ANNUAL REPORT

FOR THE CALENDAR YEAR 1948

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

W. G. Mc GINNIES, DIRECTOR

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FORT COLLINS, COLORADO

ANNUAL REPORT

of

THE ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION [1]

CALENDAR YEAR 1948

[1] Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with Colorado A & M College, Fort Collins, Colorado.

The territory served by the Rocky Mountain Station includes Colorado, Wyoming, east of the Continental Divide, and western South Dakota and Nebraska.

(Not for publication)

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INTRODUCTION

During 1948 interest in land management increased considerably in the Rocky Mountain Region. This was reflected in part by greater demands on the Rocky Mountain Forest and Range Experiment Station for information. A record number of visitors came to see experiments in progress at the several research centers and the demand for published material was great. It is hoped that this Annual Report, which is a progress report on the research activities at the Station, will provide additional useful information for the improvement of land management in the Rocky Mountain Region.

The reports of experimental work are grouped by Research Centers, starting with the Western Slope, followed by the Continental Divide (Fraser Experimental Forest), Front Range (Manitou Experimental Forest), and the Central Plains Experimental Range. This grouping by geographical units serves two purposes: (1) It brings out the interrelation of the three main lines of work--watershed, forest, and range research; and (2) it brings together current information applicable to particular locations. However, this grouping does make it necessary for the person interested in only one subject to look in several places for all the information on that subject. This may be done readily, however, by reference to the Table of Contents.

Some of the more timely items in the report are listed below.

Capacity of soil to absorb water is strongly influenced by grazing use, Pages 4 and 41.

Snow storage is increased by timber cutting in spruce-fir forest, Page 23.

Range reseeding studies are providing guides for range improvement programs, Pages 10, 49, and 62.

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2,4-D is effective in sneezeweed control and offers promise for control of other undesirable plants, Page 19.

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Grazing studies continue to show advantages of moderate grazing, Pages 45 and 51.

Good tree reproduction is found in bug-killed Engelmann spruce areas, Page 29.

Lodgepole pine plots show small gains 7 years after cutting, Page 35.

This research center was established in 1946 to investigate problems in range and watershed management on the Western Slope of Colorado. For the past 2 years research has been conducted out of Delta at various localities throughout the territory. As yet, experimental forests or ranges have not been set aside.

Several range studies in western Colorado were being supervised from Fort Collins at the time the research center was organized. They included reseeding, control of sneezeweed, and pocket gopher investigations. They were transferred to the research center and have been continued as part of its program.

Considerable time and effort during the past 2 years have been spent analyzing the problems of the Western Slope as a basis for guiding the future research program. The problems of this region are highly complex due to its variable physical characteristics and land use. Information on the character and extent of natural resources had to be assembled from numerous sources before an effective analysis could be made. The report of the problem analysis is now complete, except for minor revision and editing.

In the meantime, investigations of important watershed problems were started. Infiltration tests were made, and stream-gaging stations were established to measure the effect of timber cutting on stream flow. Range studies were expanded, especially in reseeding.

The status of present investigations and some of the results obtained are discussed below.

WATERSHED MANAGEMENT

Partial timber cutting did not change quality of water

The Red Sandstone experimental watersheds of 1/2 to 1-1/2 square miles in size and located in the headwaters of the Eagle River were established in the fall of 1947 to determine the effect of commercial timber cutting on the amount, distribution, and quality of stream flow. Continuous stream flow records were taken on three forested watersheds from the middle of April to the middle of October 1948. This was the first complete season of record as only 1 month's record was obtained in the fall of 1947, with measurements being discontinued during the winter period.

Some information on the effect of timber cutting on water quality is already available. So far the stream flow from all the watersheds has been clear. There was no difference in suspended sediment or chemical content of stream flow produced during the high spring run-off period, and all waters were rated excellent for domestic and other uses. Slightly over 100 acres of Watershed No. 3 were cut over, with the cut-over area located directly upstream from the gaging station and amounting to 14 percent of the timbered area and 9 percent of the watershed. In October, when the gaging stations were closed, clear stream flow still occurred from the partially cut-over watershed on which almost one-fourth of the

timbered area was cut. Results thus far obtained corroborate those of previous studies which indicated that erosion subsequent to logging is almost entirely absent in the high-altitude country of the Rocky Mountain region.

Gophers and livestock influence infiltration capacity

In order to obtain some immediate answers to the important watershed problems of soil stabilization, productivity, and water yield, a portable rainmaker was used during the past field season. Relative rates of surface run-off, infiltration, and erosion from depleted vegetative types and those in various stages of recovery were obtained. Total protection from livestock and ranges representing various degrees of use were sampled. The influence of pocket gopher activity on watershed values was also measured.

Portable rainmaker equipment, known as the Rocky Mountain Infiltrometer, was used, including accessory equipment for measuring erosion. In addition to infiltration and erosion, certain related factors were measured. These included live and dead organic materials above ground, herbaceous plant composition and density, slope, aspect, soil profile, soil texture and moisture penetration. Only data on infiltration capacities have been analyzed and are reported here.

The average infiltration capacity during the last 20 minutes of the 50-minute run is given in all presentations.

Infiltration studies during 1948 were designed to measure the effect of cattle grazing and pocket gophers on watersheds of summer ranges and the effect of lighter grazing use on the recovery of watersheds in the sagebrush and pinon-juniper types. A summary of these tests is presented for each location.

The effect of cattle grazing and pocket gophers on the infiltration capacity of summer range

Location --	Grand Mesa National Forest. A cooperative study between the Rocky Mountain Forest and Range Experiment Station and Fish and Wildlife Service established in 1941 to determine the influence of pocket gopher and cattle control on range forage production and grazing capacity.
Elevation --	10,000 feet.
Cover types --	Weed and sagebrush; parks in spruce-fir type; dominant weeds are sneezeweed, lupine, and yarrow.
Parent rock and soil texture --	Basalt; loam.
Average slope --	6 to 10 percent.
History --	Enclosures established in 1941. Outside area was heavily grazed. Pocket gopher control on specified areas was moderately successful.

Design -- Randomized block experiment. Three blocks containing all four treatments. Total number of samples, 48.

Results --

Treatment	Infiltration Capacity
	Inches per hour
Cattle present; gophers absent	.79
Cattle present; gophers present	1.30
Cattle absent; gophers present	1.70
Cattle absent; gophers absent	3.36

These data indicate --

1. The lowest soil infiltration capacity was found on plots grazed by cattle only.
2. Where rodents are present on the cattle-grazed range the infiltration capacity is 65 percent higher.
3. When cattle are excluded but gophers are present the infiltration capacity is only slightly higher than when both are present.
4. The exclusion of cattle and gophers produces the maximum infiltration capacity. A capacity of 3.36 inches per hour under these conditions is relatively high.
5. Elimination of pocket gophers doubles the infiltration capacity where cattle are excluded.
6. Under heavy grazing use by cattle, gophers have a beneficial effect on water entrance into the soil. When cattle are absent gophers have a detrimental effect on soil infiltration capacity.
7. There is no apparent difference in infiltration capacity due to the presence or absence of sagebrush on weedy ranges at this elevation.

Effect of cattle exclusion on the infiltration capacity of native range and a reseeded area in the grassland type

Exclosure on Native Range

Location -- Uncompahgre National Forest, Tabeguache Basin.

Elevation -- 8,300 feet.

Aspect -- North.

Cover type -- Grassland park in mixed ponderosa pine and mountain brush type. Bluegrass dominant.

Parent rock and soil texture -- Morrison shale; heavy loam.

Average slope -- Inside, 7 percent; Outside, 6 percent.

Livestock use -- Cattle.

History -- Fence installed in October 1940 and kept in good condition to the present time.

Grazing intensity outside -- Estimated at 2 to 3 usable acres per animal-month. Bluegrass utilized about 80 percent.

Design -- Fence line comparison, 5 paired samples taken at random.

Results --

Infiltration Capacity (Inches per hour)		
Exclosure (No cattle)	Outside (Cattle)	Difference
3.89	.34	3.55

Reseeded Exclosure

Location -- Uncompahgre National Forest, Tabeguache Basin. (Near exclosure on native range.)

Elevation -- 8,300 feet.

Aspect -- North.

Cover type -- Grassland park in mixed ponderosa pine and mountain brush type. Fairly good stand of crested wheatgrass.

Parent rock and soil texture -- Morrison shale; clay loam.

Average slope -- Inside, 10 percent; Outside, 10 percent.

Livestock use -- Cattle.

History -- Reseeded to crested wheatgrass in October 1940 without ground preparation. Fence installed in 1940 but grazed by trespass stock until 1945. Bluegrass utilized about 80 percent outside.

Design -- Fence line comparison, 5 paired samples taken at random.

Results --

Infiltration Capacity (Inches per hour)		
Exclosure (No cattle)	Outside (Cattle)	Difference
2.80	.47	2.33

These data indicate --

1. Total exclusion of cattle on native range for 8 years resulted in an elevenfold increase in the soil infiltration capacity.
2. Partial exclusion of cattle from the reseeded area for 5 years followed by total exclusion for 3 years resulted in a sixfold increase in the soil infiltration capacity.

Comparison of moderate and heavy grazing use by cattle on the soil infiltration capacity of the sagebrush type

Frank Rice Ranch

Location --	Below west boundary of Uncompahgre National Forest, Shavano Basin.
Elevation --	7,250 feet.
Aspect --	North.
Cover type --	Sagebrush; dominant grass, Western wheatgrass.
Parent rock and soil texture --	Dakota sandstone; sandy loam.
Average slope --	Inside, 10 percent; Outside, 15 percent.
Livestock use --	Cattle.
History --	Moderately used area is enclosed with meadows. For the past 15 to 20 years this area has not been grazed by livestock during the period of hay production from May 1 to October 31. Small amount of cattle use in early spring with somewhat heavier use during November and in December until snow accumulation prevents further use. Adjacent area is heavily grazed in the spring and fall and lightly grazed during the summer period. Grasses utilized about 40 percent in moderately grazed area and about 80 percent in heavily grazed area.
Design --	Fence line comparison, 5 paired samples taken at random.
Results --	

Infiltration Capacity (Inches per hour)		
Moderately Grazed	Heavily Grazed	Difference
1.17	.68	.49

Charlie Hill Ranch

Location --	Below west boundary of Uncompahgre National Forest near Cottonwood Creek.
Elevation --	7,000 feet.
Aspect --	North.
Cover type --	Sagebrush; dominant grass, Western wheatgrass.

Parent rock and soil texture --	Dakota sandstone; loam.
Average slope --	Inside, 9 percent; Outside, 7 percent.
Livestock use --	Cattle.
History --	Moderately used area is enclosed with meadows and cropland. In general, during the past 20 years this area has received less grazing use by livestock than on the adjacent land. Spring grazing was very light between 1940 and 1944 and no spring grazing use has occurred since then. Subsequent to 1940 this area was not grazed between May 1 and October 31 and moderately grazed in the late-fall period. Adjacent area is grazed heavily in the spring and fall period. Grasses are utilized about 40 percent in moderately grazed area and about 85 to 90 percent on the adjacent heavily grazed land.
Design --	Fence line comparison, 5 paired samples taken at random.

Results --

Infiltration Capacity (Inches per hour)		
Moderately Grazed	Heavily Grazed	Difference
1.22	.53	.69

These data indicate --

Heavy grazing use by cattle in the sagebrush type on soils derived from sandstone results in lowering the soil infiltration capacity to about one-half that existent on moderately grazed lands.

Influence of moderate grazing use by horses on the recovery of soil infiltration capacity in the pinon-juniper type

Location --	Mesa Verde National Park, along 3 miles of fence line separating horse pasture from ungrazed area.
Elevation --	7,100 to 7,700 feet.
Aspect --	South.
Cover type --	Pinon-juniper; dominant grass, Fendler's bluegrass. Area under tree crowns: Juniper, 33 percent. Pinon, 22 percent. Area in open: 45 percent. No difference in tree density or extent of open areas between horse pasture and exclosure.

Herbaceous vegetation -- (Ground cover density)	Horse pasture: Grasses, 2 percent; Weeds, 1 percent. Exclosure: Grasses, 16 percent; Weeds, 1 percent. Vegetation in open areas twice as dense as under tree crowns.
Parent rock and soil texture --	Mesa Verde sandstone; fine sandy loam.
Average slope --	Horse pasture: Under crown, 10 percent; open, 6.5 percent. Exclosure: Under crown, 8 percent; open, 6.0 percent
Livestock use --	Horses.
History --	Heavy grazing use by cattle which existed in Mesa Verde National Park since 1880 was terminated in 1928. Both areas on the mesa top were grazed by horses until the fall of 1934 when a fence was completed around the present horse pasture. The entire mesa top was in much worse condition in late 1934 than the horse pasture is now. The area outside the horse pasture has been protected from livestock grazing since 1935. Grazing use in the horse pasture has varied since 1935. It was not grazed from 1943 through 1945 and stocking ranged from 8 to 17 acres per horse-month during other years. Grasses were utilized about 40 percent in 1948.
Design --	Fence line comparison of paired plots stratified under tree crowns and open areas. Three miles of fence line divided into 4 sampling plots. Total number of samples, 32.

Results --

Infiltration Capacity (Inches per hour)

	Horses Absent	Horses Present	Difference
Under tree crowns:	3.75	1.71	2.04
Open areas:	2.37	1.07	1.30

These data indicate --

1. Soil infiltration capacity averages about 1.6 times higher under tree crowns than in open areas whether grazed or ungrazed.
2. Soil infiltration rate is 2.2 times greater under protection than under grazing by horses.

Range reseeding received major attention in 1948. Although most studies were designed to test adaptability of numerous plants to the region, methods of planting were also investigated. Reseeding trials were made in conjunction with attempts to control sneezeweed and hairy goldaster with 2,4-D. Results of plantings made in past years were inspected and classified, and additional field plots and nurseries were established.

Plant control studies were conducted on a limited scale. Small plot tests established in 1946 and 1947 were examined to determine the effects of different concentrations and seasons of application of 2,4-D on sneezeweed. Commercial spraying equipment was used to apply 2,4-D to sneezeweed on larger plots in 1948. Sagebrush and scrub oak were also sprayed with 2,4-D and 2,4,5-T.

Investigations in grazing management were exploratory, and confined to subalpine grasslands. An intensive survey of the vegetation on plots included in the pocket gopher study was not made as in past years because of the little change that was evident from the previous year.

Reseeding Studies

Range reseeding research consists of the four following steps: (1) Testing native and introduced plants to determine better species and strains for seeding rangelands; (2) testing methods of seeding to determine how and when to seed most effectively and economically; (3) study of factors of the site which influence reseeding success; and (4) management of reseeded areas.

On the Western Slope we are in the first stages of seeding work, consisting mostly of forage species trials and methods-of-planting studies. In making species trials, the common procedure is to test a large number of promising plants in nurseries. Here they are weeded but otherwise are dependent on the local climate to make their growth. Species which show up well in nurseries are then tested in field plots where they are seeded under conditions which would be encountered on large range areas. On the Western Slope we have just established a major nursery in the sagebrush type and have smaller nurseries in the semi-desert (shadscale), aspen, and spruce-fir types.

Following is a report of the four nurseries, several field plot tests, and methods-of-planting studies which include methods of seedbed preparation, seed distribution, and dates of planting.

Nurseries

One hundred forty-eight forage plants tested for reseeding sagebrush lands

Nursery trials or row-plot tests were initiated in the sagebrush type in 1948 to test the adaptability of many different grasses, weeds, and browse. Located 7 miles southwest of Crawford at an elevation of about 7,500 feet, the

nursery site is representative of many depleted sagebrush lands at intermediate elevations in western Colorado. About 3 acres were fenced to exclude livestock and rabbits. The sagebrush was cleared and the seedbed prepared in July, but planting was delayed until the first week of September.

One hundred and five different species and strains of grass were planted. Thirty-two kinds of forbs and eleven browse species were also included. In general, the species being tested here have proved successful under similar conditions in other regions. Results of plantings made by the Intermountain and Northern Rocky Mountain Forest and Range Experiment Stations were reviewed in selecting the plants to be tried.

Few species look promising in nursery plots in spruce-fir zone

Two years after planting, at 10,000 feet elevation, only smooth brome rated excellent[1] in nursery plots on Grand Mesa. This small nursery was established in the fall of 1946 in a weedy park in the spruce-fir zone. The soil is a rich loam.

Thurber fescue, meadow brome, slender wheatgrass, and mountain brome were rated as fair to good. Canada wild-rye rated fair. Birdsfoot deervetch (Lotus corniculatus) and wild-rye (Elymus sabulosus) rated fair to poor. Canada bluegrass and the Superior strain of smooth brome rated poor. The following species were very poor or failures:

Big bluegrass	Intermediate wheatgrass
Bitterbrush	Russian wild-rye
Crested wheatgrass (Standard and rhizomatous)	Smooth brome (Lincoln strain)
	Stiffhair wheatgrass
Green needlegrass	Tall wheatgrass

Green needlegrass appeared quite promising after the first growing season, but it apparently winterkilled.

In 1948, tall oatgrass, bearded wheatgrass, and reed canarygrass were planted in the nursery.

Intermediate wheatgrass, mountain brome, and timothy produced excellent stands in nursery plots at 9,000 feet elevation the first year after planting

Reseeded plants developed much more rapidly in the nursery at Columbine, located on the Uncompahgre National Forest, than they did on Grand Mesa. The Columbine nursery site is a park in the aspen type. Native vegetation had been severely depleted, and hairy goldaster dominated the site. The soil is a sandy loam. Two replications of each of 24 species or strains were planted in September 1947. Planting conditions were excellent and much of the seed germinated that fall.

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[1] Plots were given a relative rating of success based on number of plants, distribution and vigor: 0 = failure; 1 - 2 = very poor; 3 - 4 = poor; 5 - 6 = fair; 7 - 8 = good; 9 - 10 = excellent.

One year after planting, intermediate wheatgrass, mountain brome, and timothy were rated as excellent. Alta fescue rated nearly as high, and three strains of smooth brome (commercial, Lincoln, and Achenbach), meadow fescue, and perennial ryegrass all produced good stands.

Grasses that produced fair stands include Kentucky bluegrass and redtop, which are generally slow to develop at high elevations. Orchardgrass also rated fair in the nursery, although it produced an excellent stand in a field plot that was planted at the same time, adjacent to the nursery.

Crested wheatgrass, including Standard, Fairway, and rhizomatous strains, produced only fair to poor stands and plants were not vigorous. The following species rated as very poor or failures:

- Alkaligrass
- Blue grama
- Green needlegrass
- Russian wild-rye
- Slender wheatgrass
- Tall oatgrass
- Western wheatgrass

Twenty-eight species were added to the nursery in the fall of 1948.

Plantings in desert nursery were unsuccessful

A small nursery was established 13 miles northwest of Delta in the spring of 1947. It is located within a shadscale and galleta type at an elevation of about 5,000 feet. The soil is a sandy loam. The area is fenced to exclude livestock and was plowed and leveled before planting. Soil moisture conditions were excellent at the time of planting, but rainfall was meager during the remainder of the growing season. Twenty species, considered to be drought-resistant, were planted. However, none came up and the nursery was replanted in September 1948 with the addition of eight new species.

Field Plots

Field plots established on sagebrush lands in 1947 illustrate difficulties of obtaining satisfactory stands of grass

The first field plot is located near Gunnison at an elevation of 7,800 feet. The site supported a thin stand of scrubby sagebrush, a few weeds, and scattered native grasses. The seedbed was prepared by plowing, disking, and leveling, and 13 kinds of grass were planted in May 1947. Soil-moisture conditions were excellent at planting time and continued favorable throughout the summer.

By September it appeared that tall oatgrass, smooth brome, orchardgrass, and crested wheatgrass produced the best stands. Close utilization by rabbits was evident, and poultry wire was placed around the exclosure. One year later, at the end of the second growing season, smooth brome and crested wheatgrass had produced the best stands, which were rated as good. Tall wheatgrass, stiffhair wheatgrass, western wheatgrass, and intermediate wheatgrass produced fair stands. Tall oatgrass and orchardgrass, which looked most promising at the end of the first growing season, were rated poor in 1948. Reed canarygrass also rated poor. Big bluegrass rated very poor, and Canada wild-rye, perennial ryegrass, and Alta fescue were failures. In spite of

the poultry fencing, rabbits continued to get into the exclosure and kept the new seedlings grazed practically to ground level. Drought conditions prevailed during the summer and fall of 1948.

The second field plot in the sagebrush type was established in July 1947 about 7 miles southeast of Rifle on Hunter Mesa (elevation, 6,000 feet). The planting site had been cleared of sagebrush and dry-farmed many years ago. It supported only low-growing Russian thistle at the time of planting. Eighteen species were drilled without further seedbed preparation. The seedbed was dry and hard, and rainfall was meager during the remainder of the growing season. By the fall of 1948 all species were rated as failures except for a very few scattered plants of crested wheatgrass.

The third set of field plots was planted near Carbondale (elevation, 6,200 feet) in July 1947. The site had been cleared of sagebrush several years ago and was plowed and disked in the spring of 1947. Eighteen species were drilled. The seedbed was loose at time of planting, but soil-moisture conditions were favorable. Precipitation was normal or above throughout the remainder of the season.

In the fall of 1948 intermediate wheatgrass and stiffhair wheatgrass appeared to be the best species. Although the plants were vigorous, they were few and scattered and the stands were rated as poor. Alfalfa, crested wheatgrass, Russian wild-rye, smooth brome, and yellow sweetclover produced a few scattered plants. Plants that failed to grow included blue wild-rye, Kentucky bluegrass, orchardgrass, slender wheatgrass, tall oatgrass, and western wheatgrass.

Additional field plots established in 1948

Several forage species were planted on a sagebrush site about 12 miles southwest of Montrose, Colorado, in October 1948. This site is within the pinon-juniper type at an elevation of about 7,000 feet. Native grasses and weeds are very sparse. Sagebrush had been cleared from the area with a bulldozer in the fall of 1947. The seed was drilled directly into the soil without further seedbed preparation. A heavy deer concentration is reported in the area, which may be quite detrimental to regrassing this and many similar areas on the Western Slope.

Field plots to test 13 grasses were established in Sanborn Park, on the Uncompahgre National Forest, in October 1948. The planting site is a small park in the ponderosa pine type at an elevation of about 8,000 feet.

Methods of Planting

Competition from native vegetation must be reduced to reseed successfully

A series of plantings, designed to test different methods of planting, was made on mountain rangelands in the summer and fall of 1946. Twelve common grasses and clovers were planted at five locations by each of four methods: (1) Plow, drill, and cultipack; (2) plow and drill; (3) broadcast and harrow; and (4) drill direct without seedbed preparation. Four plantings were made in weedy parks in the aspen and spruce-fir types, and one was made in a sagebrush park in the ponderosa pine type.

At the higher elevations, growth of the reseeded plants was very slow. One year after planting many of the reseeded species were only 1 to 5 inches high, but 2 years after seeding some plants had produced seed stalks. Even where the seedbed was plowed there was rapid invasion of weeds.

Areas that were broadcast and harrowed, or drilled direct without seedbed preparation, produced poor stands. Apparently the reseeded plants could not become established in the rank growth of weeds. Areas that were plowed and drilled, or plowed, drilled and cultipacked, made somewhat better stands.

Table 1 shows the relative success of reseeded species under different methods of planting. This rating is based on results of seeding on the Grand Mesa, White River, Routt, and Medicine Bow National Forests at elevations of 8,500 to 10,000 feet.

Table 1.--Average rating of reseeded stands 2 years after planting

Species	Plowed, drilled, and cultipacked	Plowed and drilled	Broadcast and harrowed	Drilled direct
Timothy	Fair	Fair	Very poor	Poor
Meadow fescue	Poor	Fair	Very poor	Failure
Orchardgrass	Fair	Poor	Very poor	Very poor
Smooth brome	Poor	Fair	Very poor	Failure
Slender wheatgrass	Poor	Poor	Failure	Failure
Redtop	Poor	Poor	Failure	Failure
Canada bluegrass	Very poor	Very poor	Failure	Failure
Kentucky bluegrass	Very poor	Very poor	Failure	Failure
Western wheatgrass	Failure	Failure	Failure	Failure
Crested wheatgrass	Failure	Failure	Failure	Failure
White clover	Failure	Failure	Failure	Failure
Yellow sweetclover	Failure	Failure	Failure	Failure

Timothy, meadow fescue, orchardgrass, and smooth brome made better stands than the other species, but none developed into good stands.

Competition from tarweed reduced height growth of reseeded species.--On the Medicine Bow National Forest a dense stand of tarweed (*Madia glomerata*) developed the year after planting. In the summer of 1947 a portion of the planted area was sprayed with 2,4-D, which resulted in a fairly good kill of tarweed. Height measurements of the reseeded grasses were made on both the sprayed and unsprayed areas in the fall of 1948. The following tabulation indicates that all grasses made more height growth where competition from weeds had been reduced.

Species	Average height of grasses (inches)	
	Sprayed with 2,4-D	Untreated
Timothy	27	20
Meadow fescue	29	21
Orchardgrass	37	30
Smooth brome	33	23
Slender wheatgrass	31	23
Redtop	22	18
Kentucky bluegrass	26	21

Reseeded plants do well on areas cleared of sagebrush at high elevations

A thrifty stand of sagebrush occupied an opening in the ponderosa pine at 25-Mesa on the Uncompahgre National Forest. This brush was cleared from the entire area by railing. The seedbed was prepared by four methods and eleven species were seeded with each method. As there was little understory vegetation and the soil was loose, the railing provided a good seedbed by removing the brush. Consequently, good to excellent stands of grass resulted from all four methods of seedbed preparation and seeding: Drilling direct; plowing and drilling; plowing, cultipacking, and drilling; and broadcasting and harrowing. Growth was rapid at this elevation and several grasses produced seed the year after planting. Two years after planting the following grasses were rated as good or excellent: Timothy, smooth brome, crested wheatgrass, meadow fescue, slender wheatgrass, and orchardgrass. Redtop and Kentucky bluegrass were rated as fair to good. They were slow to develop the first year but became well established in 1948. Canada bluegrass, western wheatgrass, yellow sweetclover and white clover made very poor stands.

Hairy goldaster parks were sprayed and reseeded

Seed of 15 grasses was drilled in a depleted park on the Uncompahgre National Forest in 1948. This park formerly supported a dense stand of hairy goldaster that had been reduced at least 50 percent by spraying with 2,4-D. A few native grasses were present. Seeding was done almost a year after the area had been sprayed by the local ranger. Part of the sprayed area was not seeded in order that recovery of native grasses and reinvasion of hairy goldaster could be observed.

Possibilities of reseeding sneezeweed-infested areas were explored

Certain sneezeweed areas treated with 2,4-D in 1948 were seeded with four kinds of grass approximately 3 weeks after spraying. Seed was drilled into the soil without further seedbed preparation. The object was to determine whether such areas may be reseeded successfully by this method and, if so, whether invasion of sneezeweed will be prevented or reduced.

In addition, adjoining untreated plots were heavily disked and drilled with the same grasses to compare conventional methods of reseeding with spraying and reseeding. These grasses came up soon after planting, but those on the area that was sprayed made a poor showing the first summer. A part of the

reseeded area is protected, while another part is open to grazing use. Final results of these trials will not be known for another year or two.

Monthly plantings are being made in the sagebrush type

To determine when seeding of sagebrush lands is most likely to succeed, crested wheatgrass and smooth brome are being planted each month from May through November. These grasses were chosen because they have proved successful in the locality and are widely used for reseeding similar sites. The study was started in September 1948 within the Crawford nursery and will continue for 5 years.

Results of spring and fall planting are compared on the Uncompahgre Plateau

Several grasses were planted by similar methods in the fall of 1947 and again in the spring of 1948 near Columbine Pass (elevation 9,000 feet). Most of the plants sown in the fall germinated within 2 or 3 weeks and made an excellent growth the following summer. Several produced seed. Because the ground was too wet for plowing, the spring planting could not be made until June 25. Table 2 gives the relative rating, average height, and development of the plants in September 1948.

Table 2.--September rating and development of grasses planted at two seasons near Columbine Pass

Species	Fall Planting (1947)			Spring Planting (1948)		
	Rating	Development Stage	Ave. Ht. (In.)	Rating	Development Stage	Ave. Ht. (In.)
Smooth brome	Excellent	In flower	18	Good	Seedling	5
Timothy	Excellent	In fruit	32	Very poor	Seedling	3
Meadow fescue	Excellent	In fruit	27	Excellent	Seedling	4
Orchardgrass	Excellent	In fruit	31	Excellent	Seedling	6
Intermediate wheatgrass	Good	In fruit	32	Excellent	Seedling	4
Slender wheatgrass	Good	In fruit	20	Good	Seedling	4
Russian wild-rye	Fair	Seedling	4	Good	Seedling	5
White clover	Poor	Seedling	1	Good	Seedling	1

The difference in plant development makes a comparison of stands rather difficult, but most species grew satisfactorily from either planting. Timothy produced a very poor stand from the spring planting and an excellent stand from the fall planting. Russian wild-rye and white clover appear to be making a better stand from spring planting than from fall planting.

Methods of broadcast seeding were investigated

Seed pellets of crested wheatgrass and smooth brome made by the Adams Company were broadcast on sagebrush land in 1948. Pellets were sown on small plots supporting sagebrush and on others from which the sage had been cleared. Naked seed was also sown on adjacent plots as a check. One test was made at the nursery site near Crawford and another near Montrose.

Broadcast seeding under aspen, about the time of leaf-fall, was done at three locations on the Uncompahgre National Forest. Timothy, smooth brome, and meadow fescue were sown.

Similar tests were made on a burned-over area in the oak-brush type near Somerset. Seed of smooth brome, orchardgrass, meadow fescue, and yellow sweetclover was broadcast in the ashes in September, about a month after the fire.

Plant Control

Several formulations of 2,4-D will kill sneezeweed

Tests in 1946 showed that 2,4-D is a promising herbicide for sneezeweed when applied in midsummer at a concentration of at least 0.2 percent (or 2,000 parts 2,4-D per million of water). One and one-half gallons of water were used to spray plots 1 rod square. At this rate, approximately 4 pounds of pure 2,4-D acid with 240 gallons of water would be needed to spray 1 acre of sneezeweed-infested rangeland.

In 1947 additional plots were sprayed at three different dates during the midsummer season. Some plots were sprayed about July 1 during the pre-bloom stage of sneezeweed development. Others were sprayed 2 weeks later during the early bloom stage, and still others were sprayed about August 1 when sneezeweed was in full bloom. Concentrations of 0.2 percent and 0.4 percent were used. Three formulations of 2,4-D were tested: Butyl ester, triethanol amine, and sodium salt. Mixing the 2,4-D both with distillate and with water was tried, using 1-1/2 gallons of the carrier to spray a rod-square plot. Certain plots received no treatment and others were sprayed with distillate alone.

Results 1 year following treatment show that butyl ester, triethanol amine, and sodium salt formulations will kill sneezeweed. Several weeks after treatment it appeared that the ester formulation was more effective than the amine or salt formulations. Apparently the ester kills more rapidly, but is not more effective. Earlier observations also indicated that the ester formulation was effective when applied during the entire midsummer period, from the pre-bloom to full-bloom stage of sneezeweed development, while the other formulations were effective only during the pre-bloom stage. By 1948 it was found that all formulations were nearly equally effective if applied any time from the pre-bloom to full-bloom stage of plant development.

Concentrations of 0.2 percent 2,4-D are apparently about as lethal to sneezeweed as 0.4 percent. Solutions of 2,4-D and water were as effective as those containing distillate. Some grasses were damaged by mixtures of 2,4-D and distillate, while those sprayed with the water solution became more vigorous

and increased in density following their release from sneezeweed competition. Most of the weeds associated with sneezeweed were killed or damaged by 2,4-D.

The following table shows the average density of sneezeweed, grasses, and other weeds on plots treated with a butyl ester formulation before treatment, several weeks after treatment, and a year after treatment. The plots are located on the Uncompahgre and Grand Mesa National Forests.

Table 3.--Effect of 2,4-D (butyl-ester) on the density of sneezeweed, grasses, and other weeds

Treatment	Sneezeweed			Grasses			Other Weeds		
	Before Treatment 1947	Fall 1947	Fall 1948	Before Treatment 1947	Fall 1947	Fall 1948	Before Treatment 1947	Fall 1947	Fall 1948
	Density-percent								
PRE-BLOOM									
Water solution									
0.2% concentration	2.70	0.15	0.05	1.50	2.05	3.55	7.45	1.75	4.45
0.4% concentration	4.25	0.10	0.10	1.40	2.65	4.10	8.15	1.15	2.65
Check--No treatment	2.20	2.65	1.55	1.30	2.30	0.75	6.45	9.90	7.55
Distillate solution									
0.2% concentration	1.85	0.40	0.35	1.55	2.65	3.05	5.55	1.05	3.40
0.4% concentration	2.85	0.00	0.00	1.75	2.45	2.30	7.20	1.05	3.35
Check--Distillate only	3.25	2.20	1.50	1.80	2.10	1.85	5.50	7.75	8.20
EARLY-BLOOM									
Water solution									
0.2% concentration	2.70	0.10	0.10	1.30	2.00	3.20	9.35	1.45	5.00
0.4% concentration	3.70	0.25	0.05	1.10	1.60	3.55	9.25	2.30	3.20
Check--No treatment	1.60	2.15	1.40	1.60	1.95	1.00	7.70	9.35	9.60
Distillate solution									
0.2% concentration	4.40	0.80	0.20	1.50	0.60	3.15	9.55	0.45	4.25
0.4% concentration	1.05	0.00	0.00	0.70	0.95	2.05	5.20	0.50	2.30
Check--Distillate only	3.25	2.00	3.00	1.60	2.60	1.95	9.10	4.75	6.35
FULL-BLOOM									
Water solution									
0.2% concentration	2.30	1.35	0.20	1.55	2.80	3.15	6.95	3.55	5.00
0.4% concentration	1.90	0.65	0.05	1.00	1.90	1.90	2.90	1.70	4.80
Check--No treatment	2.50	3.00	1.10	1.75	2.40	1.45	8.40	9.75	7.55
Distillate solution									
0.2% concentration	2.10	0.45	0.10	1.60	1.55	2.30	11.75	0.55	4.65
0.4% concentration	5.25	1.80	0.25	0.70	0.80	2.40	7.80	1.15	6.80
Check--Distillate only	2.60	2.75	3.30	1.30	1.80	1.25	8.65	3.40	6.80

Density of sneezeweed was greatly reduced on treated plots, and it was somewhat lower in 1948 than in 1947 on most of the check plots. The density of grasses on all treated plots had increased substantially one year following treatment, while it remained nearly the same on check plots. Density of other weeds was greatly reduced several weeks after treatment, but a fairly dense weed cover was present a year later. However, weeds were still much less abundant on treated plots than on check plots. Weeds on plots that had been sprayed were mostly annuals or seedlings of perennial weeds.

In spite of the fact that 2,4-D kills sneezeweed, it is evident that rapid reinvasion occurs on small treated areas surrounded by this poisonous plant. Many weeds that grow in association with sneezeweed are killed, and much bare soil is exposed.

Commercial spraying equipment used to apply 2,4-D in 1948

In an effort to determine practical and economical methods of controlling sneezeweed, several $\frac{1}{2}$-acre plots were sprayed by a jeep sprayer. By using fine-spray nozzles and greater pressure it was believed that adequate plant coverage could be obtained with as little as 25 gallons of water per acre. The same concentration of solution (0.2% 2,4-D) was used as in former trials, but the actual amount of pure 2,4-D per acre was reduced considerably. Plots were treated when sneezeweed was in the pre-bloom stage. Results of this spraying do not look promising.

Effect of airplane spraying with 2,4-D on range shrubs is being observed

The Colorado Extension Service sponsored several demonstrations of airplane spraying on the Western Slope in June 1948 to determine the effectiveness of this method in controlling sagebrush, scrub oak, and willows. Spraying was done near Walden, Kremmling, Granby, and Delta at one or more locations. From 80 to 100 acres at each location were sprayed by the H. E. Bollar Company of Tulsa, Oklahoma. 2,4-D was applied in the amine form at the rate of 1 pound of pure acid, 5 gallons of water, and 1 gallon of diesel oil per acre.

This Station was called upon to measure the effect of this treatment on the vegetation. Permanent sample plots were established at the time of spraying on some of the areas, and the nature of the plant cover was observed and recorded on others. Observations several weeks later revealed that willows were defoliated, but sagebrush showed little, if any, effect of treatment. Oak-brush areas were not observed. Final results of the spraying will not be known until next year.

Sagebrush and scrub oak were sprayed with 2,4,5-T

A comparatively new herbicide, 2,4,5-T, has shown promise of being more effective than 2,4-D in controlling shrubby plants in other regions. Exploratory tests to determine its effect on big sagebrush and scrub oak were made on a small area of the Uncompahgre National Forest in July 1948. Commercial ground spraying equipment was used. A similar area was sprayed with 2,4-D so that a comparison of results may be made. Little damage to the vegetation from either chemical was noticeable 2 months after treatment

except on scrub oak that was heavily sprayed. Leaves of this plant were severely scorched. Further examinations are needed to learn the final effect of these treatments.

Grazing Management

An analysis of range problems of western Colorado indicates an urgent need for restoring a desirable plant cover on depleted rangelands. Because of the promising possibilities of reseeding in fulfilling a part of this need in a comparatively short time, much of our effort to date has been concentrated on reseeding. The program is generally quite flexible and may be altered as conditions warrant.

It is generally recognized, however, that the problem of maintaining or improving the condition of grazing lands through livestock management is of greater importance. On most of the rangeland in western Colorado, livestock management is the key to range improvement and maintenance. The solution of this problem is much more complex and may require years of intensive investigation. Intensive studies in grazing management tend to be inflexible and costly, and should be undertaken only after the problems have been thoroughly analyzed. For these reasons our research in grazing management has been largely exploratory in nature thus far.

Preliminary investigations of grazing management were started on the Henderson allotment of the Grand Mesa National Forest in 1948. This cattle allotment contains sagebrush, oak-brush, aspen, and spruce-fir types intermixed with parks supporting bluegrass and Thurber fescue. It includes numerous small drainages characterized by comparatively level bottoms and steep hillsides. In 1947 the stocking rate and season of use of the allotment were adjusted to conform to the findings and recommendations of a recent range survey. Subsequent observations by range technicians indicated that the range may still be overstocked. This allotment is fairly typical of summer ranges in western Colorado, and the existing situation offers the opportunity to study numerous range problems on a practical basis.

Ten permanent transects were established in key areas of the allotment during the past summer for both administrative use and research. The step-point method was used to record plant density and composition. Future examinations of the transects will indicate what is happening to the range under the present stocking rate, and will provide a better basis for determining proper use of similar summer ranges.

Limited observations of the vegetation on several other summer ranges were made in an attempt to gain a better understanding of the ecology of subalpine grasslands. The information collected will be valuable in determining range condition and trend, and will provide a better background for intensive studies planned for the future.

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CONTINENTAL DIVIDE RESEARCH CENTER

All work at the Continental Divide Research Center is devoted to research in Forest and Watershed Management. Forest Management is concerned with the silviculture of lodgepole pine, spruce, and alpine fir, and Watershed Management primarily with the influence of timber cutting on stream flow.

Minor, short-term problems are also handled at this Research Center as the occasion demands. For example, during the past year much attention was given to the beetle-killed stands of Engelmann spruce on the White River National Forest. Extensive surveys were made to obtain an estimate of the amount and kind of living, young growth left after the insect epidemic had run its course, and to complete the picture, intensive studies were made to determine the amount of damage to young growth caused by logging the overstory of beetle-killed timber. In addition to the regular research program in Watershed Management, considerable effort went toward the installation of all instruments for the cooperative snowmelt study with the Bureau of Reclamation. This study has now reached the stage where it will begin to yield important information on snowmelt.

Important turning points were reached during the year in both Forest and Watershed Management research. The lodgepole pine harvest-cutting study, the most important project in Forest Management research at the Research Center, was inventoried completely for the first time for growth, mortality, and regeneration. With this job completed, attention will now be turned to the spruce-fir harvest-cutting study on which progress has suffered in the past due to lack of personnel. In Watershed Management, the time has been reached when plot studies have contributed sufficiently to the understanding of the influence of timber cutting on snow storage to justify the expansion of these studies to watersheds. In the immediate years which follow, watershed studies rather than plot studies will continue the flow of information on the influence of timber cutting on water yield.

WATERSHED MANAGEMENT

Stream Flow

Ten years of research at the Fraser Experimental Forest have produced much information on the role of timber cutting in watershed management. Results now obtained indicate that timber cutting, when properly done, can substantially decrease water losses from heavily forested land. It has been found that timber cutting decreases the interception of snow and rain by the tree canopy and thus increases the precipitation reaching the ground. Water losses from the soil by transpiration and evaporation are approximately constant in quantity before and after timber cutting so the increase in snow and rain reaching the ground is a net gain. Further, the rate of snowmelt is not greatly increased by partial removal of the protecting forest.

These relations have been found through plot studies only. The amount of snow and rain reaching the ground has increased on the small units of land studied. It is logical to believe that similar gains would occur on a heavily forested watershed if part of the timber were removed. It is also reasonable to believe that these increases in effective precipitation would result in increased stream flow from such a watershed. These conclusions are plausible but unproved. Plot studies are being continued to provide information on additional forest types and cutting treatments, but the present major task is to test the plot results by applying timber cutting to an entire watershed.

Twenty percent increase in snow storage effected by thinning young lodgepole pine

Thinnings applied to dense stands of young lodgepole pine continue to show benefit in increasing net snowfall. Three years of records from the thinned plots and unthinned check plots are given in Table 1. In the single-tree thinning, trees were left with an average spacing of $8\frac{1}{2}$ feet. Thinning by this method has resulted in an increase of 23.5 percent in the water content of the snowpack as measured before snowmelting begins in the spring. In the other treatment, thinning was done only around trees standing about 21 feet apart in the stand. Good trees, spaced at this distance, were selected as crop trees, and all others within a radius of 8 feet were removed. Holes 16 feet in diameter were thus made in the stand, a single tree remaining in the center of each. This method of thinning has given a 16.8 percent increase in the water content of the snowpack.

Table 1.--Net gain of snowfall in young lodgepole stands

Thinning treatment	Snow storage				Treatment gain	
	1946	1947	1948	Ave.		
	Inches of water				Inches	Percent
Single tree selection	4.52	8.45	8.03	7.00	1.33	23.5
Crop tree selection	4.25	7.91	7.71	6.62	0.95	16.8
None	3.79	6.93	6.30	5.67		
Average					1.14	20.1

Twenty-five percent increase in snow from harvest cuttings in spruce-fir forest

Snowfall reaching the ground has been substantially increased by harvest cuttings in the spruce-fir forest type. Results are shown in Table 2 for each of the 3 years since timber cutting.

Table 2.--Net gain of snowfall in spruce-fir stands

Cutting treatment	Snow storage: Before treatment	After treatment				Treatment gain	
	1944	1946	1947	1948	Ave.		
	Inches of water					Inches	Percent
Alternate clear-cut strips	5.89	10.16	15.98	14.11	13.42	2.46	22.4
Group selection	6.80	10.81	16.53	14.95	14.10	3.14	28.7
Single tree selection	6.16	10.26	16.48	14.03	13.59	2.63	24.0
None	6.78	7.16	13.58	12.15	10.96	___	___
Average						2.74	25.0

The clear-cut-by-strips treatment consisted of cutting all merchantable timber from strips 66 feet wide; alternate strips were left uncut except for the salvage cutting of scattered, decadent trees. This treatment has effected an increase in the water content of the snowpack amounting to 2.5 inches or 22.4 percent.

In the group-selection treatment, all merchantable timber was removed from circular areas 66 feet in diameter scattered over the experimental plot. One-half of the plot was covered in this fashion; from the remaining area only decadent trees were removed. This cutting has resulted in a snow-storage increase of 3.14 inches of water content or 28.7 percent.

The single-tree-selection cutting consisted of removing the mature and overmature trees wherever found on the plot. The intensity of the cut was the same as on the other treated plots, 60 percent of the merchantable timber volume being removed. This treatment has given an increase in snow storage of 2.63 inches of water, or 24.0 percent.

Test watershed is being prepared for timber cutting

A watershed study to test the plot results was started in 1940 with the selection of the Fool Creek watershed. This area of 700 acres is densely timbered and is considered to be a good sample of many other watersheds, larger and smaller, in the high lands of the Rocky Mountains. Efforts are now being concentrated to prepare this watershed for timber cutting. The construction of a logging road into the area is essential to the preparation and this was begun the past year with 2 miles of right-of-way cleared. The flow of Fool Creek has been gaged since 1940 and concurrent measurements made of snowfall, rainfall, and ground water.

Seven and one-quarter million board feet of timber on test watershed

A detailed inventory of the present forest cover was made. Data were collected on tree species, diameters, and vigor or capacity for continued growth. The results showed a total timber volume of approximately $7\frac{1}{4}$ million

board feet. Of this amount, 48 percent is lodgepole pine, 48 percent Engelmann spruce, and 4 percent alpine fir. Eight percent of the saw-log-size trees are high in vigor, 24 percent are good, 37 percent fair, and 31 percent poor. In addition to trees of saw-log dimensions, there are over 4 million lineal feet of material suitable for fence posts, mine props, and small poles.

The basal area of the timber stand was also computed since this is a good yardstick for comparing the present forest density with that following the timber cutting. It was derived by totaling the basal areas of all trees within the watershed area. The calculation revealed a total of 107,000 square feet, or 152 square feet per acre.

Watershed elevation ranges from 9,500 to 11,500 feet; slopes average 20 percent

A topographic and drainage survey was made currently with the forest inventory. The watershed is slightly over 2 miles in length, air line; the gain in elevation over this distance is 2,000 feet. Side slopes from the boundary ridge to the stream channel average about 20 percent. The main stream, Fool Creek, is dendritic in pattern, without any large tributaries. Its source is several high springs, and there are many seeps that contribute at intervals along the channel length.

Comparison of Fool Creek stream flow with that from adjacent watershed provides measure of timber-cutting effect

To measure the effect of timber cutting on Fool Creek there must be a basis for comparing the stream flow before cutting with that after cutting. A direct comparison of annual discharges before cutting with those occurring during a period after cutting would be the simplest method but would be inconclusive. Annual and seasonal differences in weather affect stream flow and produce variations which might easily mask any changes brought about by the timber cutting. To get a clear comparison of stream flow before timber cutting with that after timber cutting, the weather differences between the two periods must be taken into account. The precipitation measurements on the Fool Creek watershed provide a partial accounting of weather conditions as they affect stream flow but a better accounting results from the use of the stream flow from a second and similar watershed.

East St. Louis Creek, adjacent to Fool Creek, was selected in 1942 to provide a basis with which Fool Creek could be compared without the confusion caused by varying weather conditions. This 2,000-acre watershed will be left in its natural forest cover and the stream flow will reflect only the changes in precipitation and other weather factors which occur through the study period. Since the watersheds of the two streams lie side by side and are similar in exposure and elevation, their water yields should be closely correlated. The close correlation should still exist after timber harvesting on Fool Creek, but the flow of Fool Creek relative to that of East St. Louis may be larger or smaller. For example: During the past 5 years, the discharge of East St. Louis Creek in July has averaged 678 acre-feet, and that of Fool Creek has averaged 132 acre-feet. The flow of Fool Creek has been 19.5 percent of the East St. Louis' flow. During 5 years following timber cutting on Fool Creek, the July flow may, for example, be

23.0 percent as much as that of East St. Louis. This increase, if it occurs, will be the measure of the timber-cutting effect on the July water yields from Fool Creek.

The comparison of annual water yields, year by year, is the simplest comparison that can be made between the two streams. This has been made, using the 5 years of stream-flow record now available. The 1943 yield of Fool Creek was compared with the 1943 discharge of East St. Louis Creek and the data from other years compared in similar fashion. It was found, however, that the annual flow of Fool Creek relative to that of East St. Louis is not consistent from year to year but varies widely. The correlation between these data is poor and there is thus no firm basis in these few years of record with which to compare Fool Creek after timber cutting.

A comparison of monthly totals of stream flow has revealed much better correlation between the two streams. The May flow of Fool Creek for each year was compared with corresponding data from East St. Louis Creek. The discharges during other months were similarly compared. Fluctuations from year to year in these comparisons were relatively small and good correlations are indicated.

Flow of Fool Creek relative to that of East St. Louis changes markedly from month to month during each year

The study of monthly totals of stream flow produced some interesting side lights on the behavior of the two streams. Table 3 presents data showing one of these features. The point of interest is the great variation, month to month, in the flow of Fool Creek relative to that of East St. Louis Creek. May and June are the snowmelting months; in late May both streams are always high and in June they reach their annual peak. During these 2 months the volume of flow in Fool Creek approaches closely that of East St. Louis Creek. July, August and September are periods of water drainage. Current precipitation is meager and stream flow is almost entirely dependent on snowmelt water which has been stored in the watershed as subsurface water. During these 3 months, the flow of Fool Creek drops to less than half that of East St. Louis Creek.

Table 3.--Fool Creek flow relative to East St. Louis' flow by months.1/

	May	June	July	Aug.	Sept.
Fool Creek flow in acre-feet	78.0	375.2	131.8	51.4	22.5
Fool Creek flow as percent of East St. Louis flow	82.0	98.0	54.0	45.0	42.0

1/ Based on 5 years of record

Fifty percent of annual yield of Fool Creek is discharged in June

A second point of interest shown by monthly summaries of stream flow is found in Table 4. Here it is important to note that over 50 percent of the total annual flow of Fool Creek is discharged in the single month of June. From this peak month, the volume of flow drops rapidly to about 16 percent in July, the second highest month.

Table 4.--The distribution of Fool Creek stream flow by months1/

	Apr.	May	June	July	Aug.	Sept.	Oct.-Mar.
Monthly flow as percent of annual flow	1.9	10.8	50.7	16.4	6.1	2.9	11.2

1/ Based on 7 years of record available from this stream

Snowmelt

The study of snowmelt conducted jointly by the Forest Service and the Bureau of Reclamation is being continued and the principal installations of instruments have been completed. Data now collected for this study are snowfall and snow-storage records, air-temperature and humidity measurements, soil-temperature measurements, readings of wind velocity and direction, and solar-radiation recordings.

A comprehensive climatic station established

A climatic station has been established on West St. Louis Creek where the collection of data is largely concentrated. The site is at an elevation of about 9,400 feet with easterly exposure. Most of the data are collected from within a large clearing in the forest, about 5 acres in area, along the valley floor. A snow course of thirty stations in this clearing provides a precise measurement of the snow storage remaining at any time. Snowfall during the melt period is measured by three snow gages distributed over the area and equipped with Alter shields. Periodic measurements of the remaining snow storage combined with simultaneous readings of the snow gages provide data for computing the amount of snowmelt which has occurred. Air temperatures and humidities, which have influenced the snowmelt, are recorded by a hygro-thermograph housed in a large, weather-instrument shelter mounted 6 feet above the ground. Maximum and minimum thermometers and psychrometric thermometers, geared for whirling, provide checks on the hygro-thermograph operation. Soil temperatures, for information on soil freezing and contribution to snowmelt, are provided by a soil-thermograph unit buried at a depth of 4 inches below the soil surface.

Wind velocities measured at three elevations

Since it is known that air turbulence has an effect on snowmelt rates, a rather elaborate installation of anemometers has been made to measure wind velocities at three elevations above the snow surface. Near the center of the clearing, a 45-foot wooden tower has been erected and anemometers mounted at the top and at midheight. A recording wind vane on the tower top completes the tower installation. A movable snow-level anemometer likewise has been installed. Anemometers and the vane are wired to a multi-pen recorder in a nearby shelter where continuous records are traced of wind velocities and directions.

Comparable wind measurements made in adjacent forest

Relationships between snowmelt and weather conditions are altered by forest cover because the weather factors themselves are altered. Wind velocities are especially modified by tree cover; and knowledge of the amount of modification is desirable in applying the results of the study to forested watersheds. To get this information, a second tower has been erected within the mature lodgepole forest surrounding the 5-acre clearing. Here, the anemometer installations of the open site have been duplicated. These instruments are also wired to the automatic recorder to secure continuous and comparable data.

Solar radiation measured

The measurement of solar radiation is important to the study, but could not be done on the Fraser Experimental Forest because of the lack of electrical power. As an alternative, a pyrheliometer and recorder were installed by the Bureau of Reclamation at Shadow Mountain Dam about 25 miles away. The elevation at this site is about the same as that of the Experimental Forest and the weather is usually similar. The radiation data should thus be applicable to use with the temperature, humidity, and wind records.

Stream-flow data from established gages will also be used

Other data useful to the study are stream-flow records which have been collected from three streams on the Forest for several years. The relationships between the snowmelt flow of these streams and weather conditions are being used to test the results obtained from local measurements taken at the West St. Louis climatic station.

Compilations of data collected to date are now being made by both cooperating agencies and preliminary analyses may soon be started.

Fish environment as affected by timber cutting is subject of a new study

Interest by the Colorado Game and Fish Department in the effect of timber cutting on trout streams has led to a new study on Fool and East St. Louis Creeks. The study, undertaken cooperatively by the Colorado Game and Fish Department and the Forest Service, is concerned with the conditions

in the two streams as they pertain to trout life. During the past year, water temperatures in Fool Creek have been taken weekly. Both streams were inspected by a fish specialist and sampled for animal life used by trout for food. These temperature and animal-life measurements will be continued after the timber harvesting on Fool Creek watershed. They will form a basis for judging the effect of timber removal on trout environment.

Present data on the temperature of Fool Creek are of interest in showing the low temperature attained even in midsummer. The first reading was taken on May 24, soon after the stream channel became clear of snow. The temperature on this date was 33.5 degrees Fahrenheit. The highest temperature observed was 46 degrees at 3:45 p.m. on August 13.

FOREST MANAGEMENT

Reproduction and Stand-Condition Survey in Beetle-Killed Engelmann Spruce Stands

A severe wind, with recorded gusts of 60 to 75 miles per hour in some places, swept the Colorado forests in mid-June in 1939. Windthrow was especially heavy among the naturally shallow-rooted lodgepole pine and Engelmann spruce trees, and particularly so on exposed areas and on the windward side of forests. The large number of fallen spruce trees on the White River National Forest provided a favorable habitat for the endemic population of Engelmann spruce beetle (Dendroctonus engelmanni Hopk.).. Because the fallen trees were buried beneath snow, the broods of beetles were protected during the winter and spring from their natural enemy, the woodpecker. Under these conditions the beetle population developed rapidly, and in a short time the original source of food was consumed. The next movement of the beetles was into the standing trees where they have subsequently wrought extensive damage.

From extensive surveys it is estimated that between 3 and 4 billion board feet of Engelmann spruce timber has been killed. Reconnaissance surveys have indicated that in localities of heaviest infestation, from 96 to 99 percent of the spruce trees 7 inches d.b.h. and larger have been killed. However, no information was available on the portion of the stand under 7 inches that might be living or dead.

In order to obtain a better understanding of the stand conditions after the insects had run their course, a study was made during the summer of 1948 with the following objectives: (1) To determine the number of seedlings, saplings, and trees left after the beetle infestation has subsided; (2) to determine how much of the stand under 7 inches d.b.h. is living and how much is dead; (3) to determine what proportion of the living stand is destroyed in the process of logging beetle-killed timber by the several logging methods; and (4) to map, if possible, those areas where artificial regeneration measures will be required to re-establish a forest cover.

A complete inventory of living trees from the smallest seedling to the largest tree was made on four 5-acre plots prior to logging and then again after logging was completed. Each plot was logged by a different

method. In addition to the before- and after-logging study, extensive stand-condition surveys were made of both virgin stands and stands that had been logged as salvage operations since the beetle epidemic began.

Beetle-killed forest supports a good stand of young growth

Although the overstory of spruce (trees 8 inches d.b.h. and larger) was practically all killed (see Fig. 1), there remains an abundant understory of seedlings, saplings, and poles to develop into a new forest. In addition to the living spruce, there is a stand of alpine fir that is even more abundant than the spruce. In the uncut forest, the number of living spruce trees was found to vary from a low of 461 per acre to a high of nearly 2,500. The number of fir trees per acre was found to vary from a low of 612 to a high of 4,688. The smallest number of both spruce and fir seedlings, saplings, and poles per acre was 1,073 while the greatest number was 6,575. The average number of seedlings for all areas examined was 3,068. Table 5 shows that there are a large number of living spruce 2 inches d.b.h. and larger. This is of considerable importance because these are the trees that will supply the seed needed to regenerate the forest naturally and they are also the trees that will provide the next timber harvest.

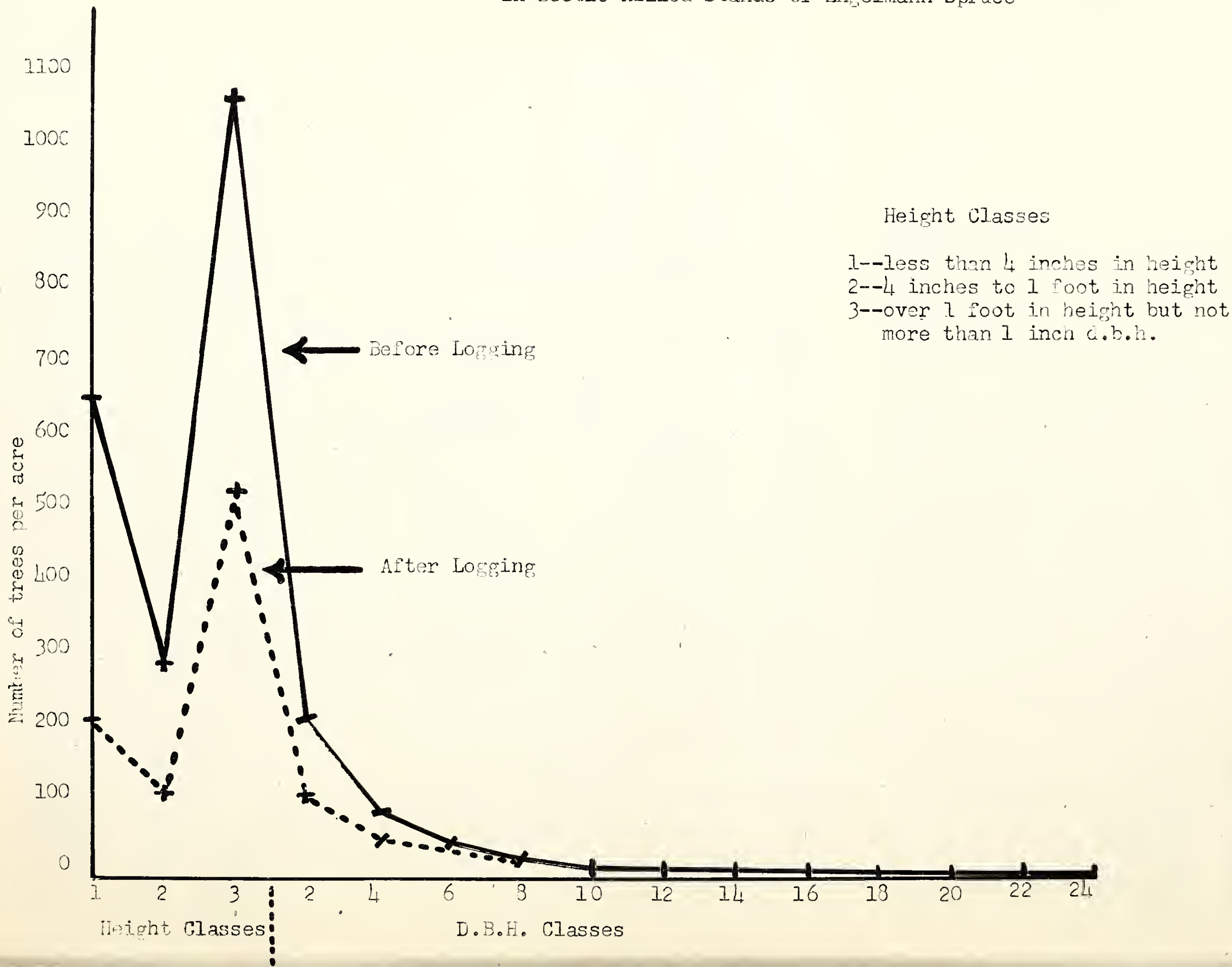
Table 5.--Average number of living spruce per acre left in beetle-killed spruce stands on the White River National Forest

Height and d.b.h. classes	Intensive survey 1/		Extensive survey 2/	
	Before logging	After logging	Uncut stands	Cutover stands
Under 4" high	504	129	530	107
4" to 1' high	184	71	266	94
1' to 1" d.b.h.	294	135	405	133
2	62	36	57	101
4	32	22	26	37
6	16	14	19	24
8	10	8	7	11
10	2	2	4	7
12	1	1	2	2
14			0.4	0.6
16			0.3	-
18			-	-
20			-	0.1
22			0.1	-
Total	1,105	418	1,317	517
Total 2" d.b.h. and larger	123	83	116	183

1/ Data obtained from the same areas before logging and again after logging.

2/ For the extensive survey the cutover areas sampled are not the same areas surveyed as uncut stands, but represent entirely different areas.

Fig. 1. Average Number of Living Seedlings, Saplings, and Trees (Both spruce and fir) Per Acre Before and After Logging in Beetle-Killed Stands of Engelmann Spruce



One-half the reproduction is destroyed in logging

Conditions in the logged stands were not as favorable as those in uncut stands. On the average, logging destroyed 62 percent of the spruce, 48 percent of the fir, or an average of 54 percent of both spruce and fir. Tallies made in 11 localities showed that after logging was completed there remained an average of 481 spruce and 619 fir, or an average total per acre of 1,100 living trees of all sizes. Of these 1,100 trees, 147 spruce and 164 fir were 2 inches d.b.h. and larger. Aside from demonstrating that some seedlings must be sacrificed in logging, these results emphasize the need for exceptional care in logging stands of beetle-killed spruce. Very little seed is available from seed trees so that the advanced growth now on the ground must be given every opportunity to develop into a future forest.

Young stand is well distributed throughout beetle-killed stands

The number of seedlings per acre does not completely describe the stand condition. A small number of well distributed seedlings could develop into a better, more uniform forest than would a large number of seedlings or trees that were concentrated on a relatively small portion of the area. The data in Table 6 give the stocking before and after logging. Stocking was measured on the basis of one or more seedlings, saplings, or poles per 1, 2, and 4 mil-acres. A minimum of 1,000, 500, and 250 uniformly spaced trees per acre provides full, or 100 percent stocking when the unit of area is 1, 2, and 4 mil-acres respectively. Table 6 shows that the distribution of living trees is quite uniform in the uncut stands, and that even after logging is completed, stocking is at the rate of 68 percent on the 2 mil-acre basis and 82 percent on the 4 mil-acre basis. Stand distribution such as this is not too unsatisfactory when it is considered that the average mature spruce stand contains from 100 to 150 trees per acre 10 inches d.b.h. and larger.

Table 6.--Percentage of forest area stocked before and after logging on the basis of 1, 2, and 4 mil-acres as the unit of measure

Plot No.	Percentage of area stocked: Before logging, Mil-acre units			After logging, Mil-acre units			Losses due to logging, Mil-acre units			Beetle-killed trees 1/	Volume killed spruce 2/
	1	2	4	1	2	4	1	2	4		
	Percent			Percent			Percent			No.	M.b.m.
1	65.4	83.4	94.8	48.9	66.8	83.6	16.5	16.6	11.2	61	24
2	85.1	96.4	99.6	48.3	66.2	76.6	36.8	30.2	23.0	155	46
3	85.7	95.0	99.2	53.7	71.0	84.8	32.0	24.0	13.4	159	48
4	61.0	79.6	94.4	54.2	71.2	87.2	6.8	8.4	7.2	140	27
Av.	76.2	89.9	97.4	50.9	68.5	82.6	25.3	21.4	14.8	129	
Extensive Survey Av.	75.3	86.6	95.9	45.3	65.1	82.3					

1/ No. trees per acre 10" d.b.h. and larger
2/ Per acre 10" d.b.h. and larger

The amount of reproduction destroyed depends upon the logging method and the volume cut

A 5-acre plot was established on each of four different logging operations. A count was made of all living seedlings, saplings, and poles on 20 percent of the area of each plot prior to logging and then again after logging. These data are given in Table 7. Each area was logged by the following method:

Plot 1.--Pulpwood operation, ground-skidding of full tree lengths with D-4 Caterpillar crawler-type tractor without dozer attachment.

Plot 2.--Saw log operation, clear-cutting in alternate 200-foot-wide strips. Short logs were cut in the woods; skidding roads were cleared with dozer, with one or more skidding roads the length of the strip. Logs were bunched along skid roads with horses. Skidding with a dozer-equipped TD-5 International crawler-type tractor drawing a light, home-made sulky.

Plot 3.--Saw log operation; short logs were bucked in the woods, ground-skidding with D-4 Caterpillar crawler-type tractor without dozer attachment.

Plot 4.--Pulpwood operation, 100-inch logs were cut in the woods and ground-skidded with horses.

Table 7.--Number of seedlings, saplings, and poles per acre, of all species, before and after logging in beetle-killed stands of Engelmann spruce

Height and d.b.h. classes	Before logging				After logging				Percentage loss due to logging			
	Plot number				Plot number				Plot number			
	1	2	3	4	1	2	3	4	1	2	3	4
	Number				Number				Percent			
0 to 4"	833	919	596	298	363	143	152	202	56.4	84.4	74.5	32.2
4"to 1'	231	308	393	256	117	94	161	98	49.4	69.5	59.0	61.7
dbh												
1'to 1	400	1,555	1,634	714	295	574	633	628	26.2	63.1	61.3	12.0
2	153	275	310	130	93	128	124	114	39.2	53.4	60.0	12.3
4	101	111	77	82	70	50	40	72	30.7	55.0	48.1	12.2
6	68	45	26	56	58	31	17	50	14.7	31.1	34.6	10.7
8	43	14	18	28	33	8	9	28	23.3	42.9	50.0	0.0
10	25	9	8	8	23	6	5	8	8.0	33.3	37.5	0.0
12	14	6	5	2	14	4	3	2	0.0	33.3	40.0	0.0
14	12	2	2	6	11	0	2	6	8.3	100.0	0.0	0.0
16	6	3	1	-	6	2	0	-	0.0	33.3	100.0	---
18	3	2	2	-	3	1	2	-	0.0	50.0	0.0	---
20	3	1	-	-	3	1	-	-	0.0	0.0	---	---
22	2	-	-	-	2	-	-	-	0.0	---	---	---
28	1	-	-	-	1	-	-	-	0.0	---	---	---
Total	1,895	3,250	3,072	1,580	1,092	1,042	1,148	1,208	42.4	67.9	62.6	23.5
Total 2" +	431	468	449	312	317	231	202	280	26.4	50.6	55.0	10.3

Although considerable variation in stocking on the four plots existed prior to logging, there were no outstanding differences in the proportion of the area stocked after logging (see Table 6). Horse-logging of 100-inch pulpwood sticks caused the least damage to reproduction (Plot 4), followed by ground-skidding of full tree lengths by light tractor(Plot 1).

Reproduction losses vary directly with the volume of timber cut

In interpreting these results, however, other factors should be taken into consideration. Reproduction losses as a result of logging appear to be correlated with the volume of wood removed as well as with the logging method employed. It is reasonable to expect that the greater the number of trees felled and skidded, the greater will be the damage to the reproduction, sapling, and pole stand. Careful logging decreased logging damage.

At the time that Plot 1 was being logged there was some question as to the desirability of permitting the skidding of full-length trees. As the logging operator desired to continue tree-length logging he may have been anxious to prove that full-length skidding did no more damage than the skidding of shorter lengths and, therefore, exercised greater care in logging the plot than was exercised in logging other stands. It is believed, however, that the operators logging Plots 2, 3, and 4 did not exercise greater care than normal in logging the plots. In fact, it is very possible that the operators logging Plots 2 and 3 exercised no care whatsoever. Although horse-logging (Plot 4) proved least destructive to the living stand (see Table 7) the study points out that tractor-logging can also be done with a relatively small amount of destruction to the understory when there is a desire to do so.

Extensive and intensive surveys show striking similarity in stocking

The distribution of the living stand was found to be essentially the same for both the extensive stand survey and the intensive survey of the four logging plots. This is shown by the averages given in Table 6 and indicated that the intensive logging plots were a representative sample of beetle-killed stands. The data in Table 6 show that for beetle-killed stands in general, the distribution of living seedlings, saplings, and poles is quite adequate to develop a well stocked forest in the future. However, since the number of trees per acre in the 2-inch d.b.h. class and larger is not sufficient to provide a fully stocked stand, these trees will be somewhat open-grown, and many of them will be more limby than they would be if they had developed in a denser stand.

Trees less than 6 inches are seldom attacked by beetles

Although previous reconnaissance data had shown that most of the spruce trees larger than 7-inches d.b.h. were killed by the beetle, no specific information was available concerning small poles and saplings. Stand tallies made as a part of this study revealed that the spruce beetle attacked and killed no trees under the 2-inch d.b.h. class. However, as the size of the tree increased, the greater was the likelihood of a successful attack. The proportion of the stand killed in the 2-, 4-, 6-, and 8-inch diameter classes was found to be 1.1, 10.0, 30.0, and 52.0 percent respectively. Dead spruce

trees under 2-inches d.b.h. were found, but close examination proved that in most cases death resulted from a combination of suppression or fungal infection or girdling by rodents, followed by attacks of secondary bark beetles such as Ips.

The living understory provides a source of seed for additional regeneration

Maximum productivity of forest land is possible only when the soil is fully occupied. The stand-condition survey shows that after the beetle infestation has subsided, a large proportion of the land area is occupied with seedlings or larger trees (see Tables 6 and 7). Nevertheless, there are some areas that are not bearing trees in the uncut stands. In the cutover stands there are also additional areas, such as skid trails and landings, where the advance reproduction has been destroyed and restocking is necessary. Natural reproduction can follow only in the event that seed is available. Seedlings less than 4 years old rarely occurred; none, however, were found less than 2 years old. There is, then, little hope of obtaining natural reproduction from seed stored in the duff. If natural reproduction is to be obtained, seed must come from the living stand that is left.

The survey data showed that a very small proportion of the trees under 8-inches d.b.h. produced cones. Only 2 percent of the 4-inch class, 17 percent of the 6-inch class, and 64 percent of the 8-inch class produced cones in 1948. Although there are not many living trees larger than 8 inches, practically all produced cones. The proportion of spruce trees producing cones was almost identical in uncut and in cutover stands. On the other hand, more fir trees in cutover stands produced cones than in uncut stands. The apparent explanation for the difference in cone production between the two species appears to be related to the position in the stand that cone-bearing trees occupied. Spruce cone producers nearly always grew in the open or along the fringe of the stand and, therefore, had ample sunlight regardless of whether the stand was cut or uncut. Dominant and codominant fir trees were the only cone producers in uncut stands, while in cutover stands trees in the intermediate crown class produced cones as well as trees in the dominant and codominant classes. It is possible that cone production in the intermediate crown class may have been stimulated as a result of additional light being made available to the understory through cutting.

Although the seed source in these beetle-killed stands is not large, it is believed that some additional reproduction will be obtained as a result of natural seedfall.

Lodgepole Pine Harvest-cutting Study

An experiment to determine the silvicultural system best adapted to lodgepole pine began on the Fraser Experimental Forest in the winter of 1939-40. It was designed to test four partial-cutting systems and an uncut control. Each of the five treatments was replicated four times in order to provide a check on the consistency of the results. Superimposed upon the main treatments were two sets of minor treatments. This was done by the standard split-plot procedure. On the north and south halves of each plot

slash was either lopped and scattered, or burned. On the east and west halves stand improvement in the submerchantable stand was either applied or left as a check. The study comprised twenty 8-acre plots, or a total area of 160 acres.

Lodgepole pine is not adapted to heavy partial cutting

The mean annual growth by plots and by treatments is presented in Table 8. It is apparent from these data that lodgepole pine is not adapted to heavy partial cutting. A reserve stand of 6,000 board feet per acre, which would normally be considered windfirm, indicated a net growth of only one board foot per acre annually. Partial cuttings which removed all but 4,000 board feet and 2,000 board feet per acre actually indicated minus growth. In other words, growth failed to keep pace with mortality. The commercial clear-cut plots grew 11 board feet per acre annually. Positive rather than negative growth occurred in this instance because no merchantable-sized trees were left after logging that might result in board-foot mortality. Had cubic-foot growth been computed for the stand below as well as above 10.0 inches d.b.h., growth would have been negative in this case also. Heavy windfall on all plots contributed almost entirely to the poor showing of each treatment.

Table 8.--Average annual increment per acre of lodgepole pine under different intensities of cutting

Harvest-cutting treatment	Block means A	Block means B	Block means C	Block means D	Mean for treatment
	Board feet				
Commercial clear-cut	10.3	13.5	9.9	12.0	+ 11.4
2 M board feet reserve	- 37.6	-145.1	- 26.9	- 19.5	- 57.3
4 M board feet reserve	-268.1	17.0	- 11.2	7.5	- 63.7
6 M board feet reserve	- 54.3	25.0	- 28.3	61.6	+ 1.0
Virgin	- 88.7	58.2	14.8	69.9	+ 13.5

Average mortality for all treatments exceeds previous estimates

Previous studies of growth in the lodgepole pine type have indicated that average annual mortality per acre was approximately 33 board feet. In Table 9, where mortality is given by plots and treatments, the mean mortality exceeds the previous estimate approximately three times. Since the growth studies covered a much longer period after logging, it is believed that the present results reflect heavy early mortality. Subsequent determinations of growth will undoubtedly indicate a much smaller mean annual mortality when the period after cutting is much longer, and when the reserve stand has had an opportunity to develop some windfirmness.

Table 9.--Average annual mortality per acre, board feet

Harvest-cutting treatment	Block means A	B	C	D	Mean for treatment
		Board feet			
Commercial clear-cut	0	0	0	0	0
2 M board feet reserve	82.7	169.9	54.0	46.8	88.3
4 M board feet reserve	308.7	79.2	78.1	70.6	134.1
6 M board feet reserve	157.2	73.7	91.2	36.3	89.6
Virgin	122.3	36.0	71.9	31.9	65.5

Ingrowth affected by early mortality

Ingrowth, or the growth resulting from submerchantable trees moving into the 10.0" d.b.h. class, is less for the commercial clear-cut plots and the 2 M board feet reserve plots than for the remaining treatment (see Table 10). This reduction in growth was the result of heavy windfall losses in trees below merchantable size in the heavily cut plots. The more lightly cut plots such as the 4 M board feet reserve and the 6 M board feet reserve plots lost proportionately less trees, and therefore show considerably more ingrowth. Because of the many trees normally left in submerchantable stands of lodgepole pine, the amount of ingrowth should increase as the period after cutting increases. The rate of increase will, however, be greater for the lightly cut plots where a good growing stock of submerchantable trees still remains.

Table 10.--Average annual ingrowth per acre, board feet

Harvest-cutting treatment	Block means A	B	C	D	Mean for treatment
		Board feet			
Commercial clear-cut	10.3	13.5	9.9	12.0	11.4
2 M board feet reserve	19.4	12.4	11.4	12.1	13.8
4 M board feet reserve	16.9	34.8	24.9	28.5	26.3
6 M board feet reserve	35.4	30.5	25.6	36.3	31.9
Virgin-12 M board feet	18.5	33.8	31.4	40.4	31.0

Only a small amount of growth is available from overmature stands of lodgepole pine

While the virgin or control plots produced the greatest board-foot growth of all treatments, the actual amount of growth was small (13.5 board feet per acre). Charged against the virgin plot growth was 65 board feet of mortality. This is believed to be greater than the true mortality for such stands because it includes wind damage caused by the proximity of virgin plots to heavily cut plots. One plot, for example, that laid adjacent to a clear-cut plot was heavily damaged on its windward side. Mortality upon it was 122 board feet per acre annually. In an extensive, uncut forest of lodgepole pine it is believed that 40 to 50 board feet is a closer estimate of mortality than the average for the 32 experimental acres (see Table 9). If this is true, growth in virgin stands of lodgepole pine is in the neighborhood of 30 to 40 board feet per acre annually. However, from this must be subtracted the annual decrement caused by wood-rotting fungi to obtain net growth.

Rapid regeneration has followed cutting

Before cutting all plots averaged approximately 1,600 seedlings per acre. Logging destroyed 43 percent of these seedlings, leaving only 900 survivors per acre. Seven years after cutting the number of seedlings per acre had increased threefold and stocking had risen from 37 percent to 68.0 percent (see Table 11). The increase in stocking was the greatest for the clear-cut plots and the least for the lightly cut plots. However, since the growing stock left after cutting was not considered in the stocking and seedling survey, a true picture of the present over-all condition of each treatment is not given by the stocking figures alone. For example, if the growing stock left under each treatment were allotted its proportionate share of ground area, stocking would now be practically 100 percent for all plots. The striking point here is that this condition has been reached in only 7 years after logging. Very little if any ground has been left unproductive for any appreciable period. Ultimate growth should therefore be at a maximum and influenced only by site, and the manipulation of the growing stock by successive harvests.

Table 11.--Progress of regeneration in lodgepole pine 7 years after logging

Treatment	After logging (1941): Seedlings	After logging (1941): Stocking	7 yrs. after logging: Seedlings	7 yrs. after logging: Stocking	Gain: Seedlings	Gain: Stocking
	No.	%	No.	%	No.	%
Commercial clear-cut	1,088	39.4	3,728	80.1	2,640	40.7
2 M board feet reserve	907	39.4	3,168	76.1	2,261	36.7
4 M board feet reserve	1,021	39.9	3,538	76.2	2,517	37.3
6 M board feet reserve	628	29.8	2,179	62.2	1,551	32.4
Virgin-12 M board feet	854	-	1,494	51.4	640	-
Average	900	37.1	2,821	68.0	1,922	36.8

Lopping and scattering slash retard regeneration

Previous work on burning versus lopping and scattering lodgepole pine slash proved quite conclusively that burning is undesirable because it resulted in the establishment of too many seedlings. Since much of the seed which gives rise to excessive regeneration falls from slash before it is burned, swamper burning was applied to one-half of the harvest-cutting plots. By using swamper burning practically all seed was destroyed by fire before the persistent cones opened. It was hoped that this treatment would eliminate the fire hazard created by slash without the disadvantage of producing excessive regeneration. Table 12 indicates that swamper burning was only partially successful. Lopping of slash is still to be preferred over burning. Stocking on the lopped and scattered area was only 4.6 percent less than the burned area, but contained 27 percent less seedlings per acre.

Table 12.--Influence of lopping and burning slash on regeneration of lodgepole pine
(Average number of seedlings established per acre since cutting)

Treatment	Piled and burned		Lopped and scattered	
	Seedlings	Stocking	Seedlings	Stocking
	No.	%	No.	%
Commercial clear-cut	2,908	83.7	2,422	77.6
2 M board feet	2,648	81.8	1,783	70.4
4 M board feet	2,774	76.6	2,049	75.7
6 M board feet	1,834	63.4	1,123	60.9
Virgin-12 M board feet	346	52.9	277	49.9
Average	2,102	71.5	1,531	66.9

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All of the research for the Front Range Research Center, with the exception of some reseeding studies, is concentrated at the Manitou Experimental Forest. No new studies were initiated during 1948, but treatment was applied to six experimental watersheds and some phases of reseeding were expanded.

The Manitou Experimental Forest is typical of most of the Front Range area. The problems under investigation deal primarily with watershed management for the reduction of floods and erosion, including grazing management on native ranges and the restoration of depleted lands. These are the most important problems of the Front Range.

The 1948 season was generally dry. Only 12.38 inches of precipitation was recorded during the year as compared with 25.80 inches in 1947 and a long-time average of 16.75 inches. The drought conditions during 1948 were offset to some extent, especially during the early part of the growing season, by the carry-over of soil moisture from 1947. The most noticeable effect of the drought occurred on reseeded pastures and hay plots. Very little regrowth occurred during the late summer and fall, and one phase of the grazing study on reseeded pastures had to be omitted for this reason.

Some of the 1948 research results with comparative data from previous years are presented in the following pages.

WATERSHED MANAGEMENT

The influence of land use on run-off and erosion continues to be an important question in the watershed management program at Manitou Experimental Forest. Basically, the problem is to learn about water behavior after it reaches the land as snow or rain. In the Front Range, studies are made to determine optimum conditions for entry of water into the soil reservoir where it is useful for on-site development of vegetation and downstream supply.

In a region such as the Colorado Front Range where water is a critical resource, the principles of watershed management are paramount. However, other uses of the land that do not damage the water resource should be encouraged. On lands suitable for both grazing and water yields the matter of conservative use becomes an extremely important factor in maintaining proper balance between the two. The same is true of lands where timber and water resources are combined. In the past 10 years a number of separate studies have been carried on at Manitou Experimental Forest to provide some answers to the problems of multiple use. Primarily, these studies have dealt with the range-water combination of resources, but some attention has also been given to watershed management on timber lands as well as some of the more fundamental questions of stream-flow behavior, storm patterns, and floods.

Increasing grazing pressure decreases amounts of water entering the soil

One of the primary objectives of a large-scale pasture study at Manitou Experimental Forest has been to determine how grazing affects the water resource. Six pastures averaging 300 acres in area have been studied since 1941 to determine the over-all effects of light, moderate, and heavy grazing by cattle. One of the effects which is showing up with increasing clarity is the reduction in opportunity for precipitation to enter the soil as grazing intensities are increased.

The entry of moisture into the soil is measured by applying a given amount of water to an enclosed plot and measuring the residual which runs off the soil surface. The difference is the amount entering the soil, or "infiltration," which is expressed in inches of rainfall per hour. Use is made of a portable plot in order to get an adequate sample of all conditions within each pasture. Although this method of measurement is the best yet devised for infiltration studies, certain factors are encountered which tend to obscure the real effects caused by different grazing intensities. One of these factors affecting infiltration is the variation in grazing within a single pasture which is theoretically utilized at a uniform intensity. In an effort to meet such problems two changes were made in the field methods for the 1948 season; the number of samples per pasture was increased and an estimate of grazing intensity was made at each sample location.

In order to increase the number of samples it was necessary to make use of a small square-foot plot frame instead of the bulkier equipment used in previous years. As a result it was possible to increase the number of samples from 6 to 16 per day. The increased number of samples covered the range of variation in the pastures more completely and tended to offset the sacrifice of precision in an individual plot measurement. Each pasture was covered with 96 randomly located samples or a total of 576 for the entire set of six pastures. Samples were evenly divided among the two distinct vegetative cover types: open grassland and timber grassland.

The results are shown as average infiltration rates in inches per hour (Table 1). Part A of Table 1 is a compilation based upon pasture averages for each of the three grazing intensities. The third line, which is the average of both cover types, shows a notable trend indicating a reduction in the infiltration rate with increased grazing intensity.

Certain fluctuations are evident in the first and second lines representing individual cover types. These may be due to a disproportionate sampling of heavily grazed areas in a lightly grazed pasture or of lightly grazed zones in a heavily grazed pasture. For this reason the data have also been summarized by intensity of grazing noted at each individual sampling spot (Table 1, Part B). Each estimate of grazing intensity was based upon vigor of the grass, stubble height, and general appearance of the area immediately surrounding the infiltration plot. The criteria for judging at a sampling point were identical to those used in the over-all appraisal of grazing intensity by pasture units. The resulting analysis brings out a more striking relationship between grazing intensity and infiltration rates -- one that maintains a consistent trend in both cover types as well as for the average of the two.

Table 1.--The influence of grazing intensity upon infiltration rates
(All data in inches per hour)

A. Summary of average infiltration rates by pastures

Cover type	Grazing intensity (Pastures 1&4) Heavy	(Pastures 3&6) Moderate	(Pastures 2&5) Light	Average of grazing intensities
Open grassland	2.198	2.845	2.702	2.582
Timber grassland	2.888	2.892	3.285	3.022
Average of cover types	2.543	2.868	2.993	2.803
No. of samples	192	192	192	576

B. Summary of average infiltration rates by grazing intensity estimated at each plot

Open grassland	2.103	2.631	3.170	2.582
Timber grassland	2.633	3.012	3.223	3.023
Average of cover types	2.305	2.808	3.203	2.803
No. of samples	168	202	206	576

This latter summary serves to substantiate the results obtained from pasture averages and indicates that even under light and moderate stocking certain areas are likely to be heavily grazed with consequent dangerous reduction in moisture intake by the soil. These zones of heavy use should govern rates of stocking if grazing pressure cannot be distributed more evenly by management methods.

Permanent bunchgrass plots show increased run-off and erosion as a result of cattle grazing

Since 1938 run-off and erosion have been measured from a series of six permanently established plots in the bunchgrass type at Manitou Experimental Forest. Each plot is 1/100 acre in area and equipped with catchment tanks to provide a measure of run-off and soil movement produced by natural precipitation.

In August 1941 treatment was applied by hand-clipping to simulate grazing, but in succeeding years cattle were used and were controlled with

an electric fence. Each year two plots have been grazed heavily, two moderately, and two have been left untouched. Since treatment began there have been a total of 59 storms during late spring, summer, and early-fall months, causing measurable run-off, and 10 storms sufficient to produce erosion (see Table 2).

Table 2.--Run-off and erosion from bunchgrass plots since grazing treatment began in 1941

A. Run-off in inches depth

Year	Number of storms	Grazing intensity: Heavy	Moderate	None
1941	3	.02	.02	.01
1942	3	.04	.03	.03
1943	6	.16	.16	.12
1944	7	.66	.43	.25
1945	13	1.96	1.05	.83
1946	4	.11	.09	.01
1947	14	.53	.25	.08
1948	9	.19	.17	.06
Total	59	3.67	2.20	1.39

B. Erosion in pounds per acre

1943	1	204	117	67
1944	4	659	402	392
1945	5	447	183	206
Total	10	1,310	702	665

It appears evident that heavy grazing causes both increased run-off and erosion whereas moderate grazing results in an intermediate increase in run-off and only negligible changes in soil movement. A large part of the soil movement came as a result of storms with a total of 0.60 inches or more precipitation. In the last 3 years few storms of that magnitude were experienced, with the result that there was no measurable erosion from any of the six plots.

Young ponderosa pine stand appears to have recovered original watershed characteristics 8 years after removal of litter

Run-off and erosion from a young ponderosa pine stand have been measured since 1938 by use of permanent plots identical in physical design with those used in the bunchgrass study. In 1941 all litter and duff were

removed from the ground surface on three of the six plots to simulate the effects of a ground fire. The results were immediate and striking. Erosion during the first year jumped from almost nothing to the rate of 4 tons per acre and run-off was more than doubled. During successive years the results of treatment diminished rapidly as new litter began to accumulate and replace that removed. There has been no erosion since 1945 because of the lack of high-intensity storms. However, the treated area has continued to produce more run-off, although the difference due to treatment has steadily diminished. Finally, in 1948 there appears to be no significant difference in run-off and to all appearances the treated and untreated plots have returned to an equilibrium.

Stream behavior is carefully observed on Missouri Gulch watershed

The fall of 1948 marked the end of the ninth year of stream-flow records taken in Missouri Gulch watershed. This drainage covers an area of 4,800 acres on the western flank of the Rampart Range. It is, in reality, a large outdoor hydrologic laboratory where the relationship between precipitation and run-off are carefully studied to learn more about the water cycle of the Front Range.

Snow and rain are measured by gages placed at strategic spots throughout the watershed; in some cases these are recording gages which give the time of occurrence and the intensity of rain or snowfall. Stream flow is measured in a self-recording flume which gives the volume of flow for given time intervals. Lastly, a number of groundwater wells have been installed to give the fluctuations in the subterranean water table.

Analysis of records from this watershed give evidence of some characteristics of a general nature which may be of general applicability to Front Range drainages on granitic formations. For example, the water yield in the form of stream flow from Missouri Gulch is between 10 and 15 percent of the total inches of precipitation received. In contrast, high-altitude watersheds of the Continental Divide yield about 50 percent of the total precipitation. The Front Range, therefore, cannot be classed as a zone of high water yield.

Storm analyses indicate the relation of soil moisture to floods

A study of storm patterns from records of the Missouri Gulch drainage have given some clue to the combination of events which lead to disastrous floods in the Front Range. For instance, some of the events leading to the flood of May 10, 1947, which centered in Monument and Fountain Creeks can be traced by a study of records from Missouri Gulch. While it is true that the center of the storm was on the east side of Rampart Range, enough precipitation was received on the west side to tell the story.

In contrast to many storms experienced in Missouri Gulch the one in question resulted from a moderate quantity of precipitation at relatively low intensity over the entire watershed. Records show a total of 1.31 inches received with a maximum intensity of a total of 0.51 inches per hour. The flow recorded at the stream gage was one of the highest on record. The groundwater charts showed that the water table was relatively high, an indication of saturated soils. Only a small amount of soil storage was available to receive the storm, with the result that excessive amounts of water entered the streams by surface and subsurface flow. In contrast to the 10 to 15 percent

annual water yield characteristic of Missouri Gulch, approximately 45 percent of the total precipitation from this storm reached the stream channel within a few hours. It seems probable that saturated soil conditions in May and early June contribute to floods during that period in the Front Range.

Small watersheds employed to test effect of vegetative changes on run-off and erosion

One of the most important questions in watershed management is determining the ideal vegetative cover for watershed protection. Earlier studies in the Rocky Mountain area have shown that aspen and grass may be as good or even better than poorly stocked young pine.

At Manitou Experimental Forest tests were started in 1948 to determine the effects of conversion from young ponderosa pine to aspen and to grass. Treatment was applied to six small watersheds, approximately 1 to 2 acres in size, on which records of run-off and erosion have been kept for a period of 10 years. Prior to treatment, all six areas had some grass and aspen intermixed with the pine. On two drainages both pine and aspen were cut to allow development of a grass cover. Two others were given a release-cutting to favor the aspen, and the remaining two were left in their original condition.

Type conversion by natural means is desired, but if this fails, artificial propagation may be necessary. Eventually it is hoped that a complete vegetative cover of the desired type can be obtained on each watershed. The effects as a watershed management measure can then be evaluated in terms of run-off and erosion which can be compared with the check areas and the results obtained during the 10 years prior to treatment.

RANGE MANAGEMENT

Management of pine-bunchgrass range

No change was made in the grazing intensity study on native bunchgrass range. This study involves the use of six 300-acre pastures that are grazed at three different rates of use during the summer period from June 1 to October 31.

1948 cattle gains were below 7-year average

All phases of the study of grazing intensity produced results similar to those in previous years. The average seasonal gain of the yearling heifers was 197 pounds per head or slightly lower than the 7-year average. Cattle from the heavily stocked pastures gained only 172 pounds as compared with 206 pounds and 214 pounds for those from the moderate and lightly stocked pastures. The previous average gains were 180 pounds per head from heavily stocked pastures, 222 pounds from moderate, and 235 pounds from lightly stocked pastures. Although the 1948 gains were low they were not as low as the gains in 1943 or 1946.

The amount of herbage produced in 1948 averaged 266 pounds per acre as compared with 251 and 277 pounds in 1946 and 1947. The heavily stocked pastures produced 163 pounds per acre, moderately stocked 380 pounds, and lightly stocked 254 pounds. The heavily stocked pastures are now producing less than half as much herbage as they were in 1942.

One important change occurred in the utilization of the pastures. During 1948 the heifers used 75 percent of the herbage produced on Pasture 1. Previous use had averaged about 60 percent. It is believed that this big increase in use is the direct result of the grazing treatment. Pasture 1 has been heavily stocked, but the treatment effects had not been as pronounced as in Pasture 4, which was also heavily stocked. Herbage production on Pasture 1 dropped from 240 pounds in 1947 to 191 pounds in 1948. The breaking point has occurred, and more rapid deterioration may now be expected.

This study has established the importance of proper stocking as a means of maintaining pine-bunchgrass ranges in good condition and obtaining maximum production from livestock. These ranges should not be stocked to exceed 35 to 40 percent use of the herbage. If they are grazed in excess of these amounts, both the production of herbage and cattle gains are reduced.

RANGE RESEEDING

In the Front Range of the Colorado Rockies there are thousands of acres of abandoned farm lands that are idle because they are no longer producing enough to justify cultivation. Additional thousands of acres of depleted range lands are no longer producing the amount of herbage that they are potentially capable of growing. Through properly planned reseeding studies these lands can be made to produce abundant herbage for the use of livestock and to stabilize eroding soils for good watershed management.

Reseeding studies at the Manitou Experimental Forest, designed to provide information on soil stabilization and methods of increasing the forage supply, include three phases of investigation: Nursery trials, field plots, and grazing management on reseeded stands.

Abandoned fields reseeded in 1946 were grazed during 1948

In 1946 two 10-acre pastures were reseeded to crested wheatgrass, two to smooth brome, and two to a mixture of these grasses and yellow sweetclover. The areas were plowed, packed, and drilled during the fall of 1945 and spring of 1946, and excellent stands of grass were obtained. Each of the 10-acre areas was divided into smaller pastures to determine the effect of grazing intensity on herbage production. A small portion of each area was used to determine the yields of hay.

During 1948, the third growing season, the areas were grazed at three intensities of use for a 6-month season, May 1 to October 31. The stocking rates for this initial grazing season were established at 1/4, 1/2, and 1 acre per animal-unit-month. Future stocking will be based on utilization to obtain desired stubble heights at the end of the grazing season. Yearling Hereford heifers were used and the cattle were rotated at weekly intervals within the small pastures.

1948 herbage yields from reseeded fields exceed those of 1947

The average yield of air-dry herbage from reseeded fields in 1948 was 4 to 80 percent greater than in 1947 (Table 3). The greatest increase occurred in stands of smooth brome which averaged 2,328 pounds of air-dry forage per acre in 1948. The smallest increase was in the mixture of crested wheatgrass, smooth brome, and yellow sweetclover. This year there was very little clover in the stand so the values for 1948 do represent a great increase in the amount of grass herbage produced. The yields from these reseeded fields in 1948 all exceeded a ton to the acre of air-dry herbage. Crested wheatgrass and stands of the mixture produced about 1½ tons to the acre.

In contrast to these high yields from the reseeded fields, areas of moderately grazed native bunchgrass range produced 380 pounds of air-dry herbage. In open parks where yields are not affected by timber cover, 673 pounds of air-dry herbage was produced. This is about one-fourth as much as the lowest yields from reseeded areas.

Table 3.--Herbage yields from reseeded fields
Manitou Experimental Forest, 1947-1948

Species	Location	Herbage yields 1947	Herbage yields 1948
		Pounds per acre, air-dry	
Crested wheatgrass	Sinclair field	2,497	2,737
	Nursery field	1,181	2,900
	Average	1,839	2,818
Smooth brome	Sinclair field	1,489	2,314
	Nursery field	1,090	2,343
	Average	1,290	2,328
Mixture	Sinclair field	2,891	3,313
	Nursery field	3,313	3,131
	Average	3,102	3,222

Hay yields from reseeded fields are equal to yields from native mountain meadows

Native mountain meadows on the Manitou Experimental Forest usually produce between 1/2 to 3/4 tons of hay per acre. Some of these subirrigated meadows have been used for hay production only during the last 12 years. Others are grazed during November and December after the hay has been cut. They are in good condition but probably are not producing the maximum amount of herbage.

Reseeded fields on the slopes above these meadows produced from 1/2 to 1 ton of hay per acre during this third growing season. The yields from these areas cut for the first time in 1948 were as follows: Smooth brome, 1,100 pounds;

crested wheatgrass, 1,696 pounds; and the mixture of crested wheatgrass and smooth brome, 2,394 pounds. These yields are air-dry weight of baled hay. Originally sweetclover was planted in the mixture of crested wheatgrass and smooth brome, but it failed to show up during the 1948 season. The beneficial effect of the legume on soil fertility is probably responsible for the higher yields of the mixture on those areas.

Cattle make good gains on both reseeded and native pastures

The average daily gain of yearling heifers grazed on reseeded pastures was slightly higher than gains on native bunchgrass range (Table 4). Maximum gains of 1.58 pounds per day were obtained on a lightly stocked pasture consisting of a mixture of native range, abandoned farm land in various stages of succession, and areas reseeded to crested wheatgrass and to smooth brome. Reseeded pastures consisting of a mixture of crested wheatgrass and smooth brome produced the next highest gains, but were not much higher than lightly stocked native bunchgrass, straight crested wheatgrass, and moderately stocked native bunchgrass pastures. Daily gains on smooth brome were only 1.29 pounds per day. Lowest gains were obtained from heavily stocked bunchgrass pastures.

Table 4.--Average daily gain for yearling heifers
Manitou Experimental Forest - 1948

Pasture type	Stocking rate	Average gain
		Lbs. per day
Mixed native and reseeded pasture (6-month season)	Light	1.58
Mixed crested wheatgrass and smooth brome (6-month season)	Moderate	1.47
Crested wheatgrass (6-month season	Moderate	1.41
Smooth brome (6-month season)	Moderate	1.29
Native bunchgrass (5-month season)	Light	1.42
	Moderate	1.37
	Heavy	1.14

Total seasonal gains were greater on the reseeded pastures because they were grazed for a 6-month season, May 5 to October 30, whereas the grazing season on native bunchgrass pastures was only 5 months, June 1 to October 20. Of the reseeded pastures the gains on smooth brome were much lower than those from either crested wheatgrass or from a mixture of crested wheatgrass and smooth brome. These seasonal gains were 226.2 pounds per head on smooth brome, 246.5 pounds on crested wheatgrass, 256.5 pounds on the mixture, and 206 pounds on the moderately stocked native pastures.

One of the greatest benefits of reseeding is this month of early spring forage produced by reseeded grasses while the natives are not yet ready for grazing.

Reseeded pastures produce more beef per acre

Although the average daily gain of yearling heifers on reseeded pastures was only slightly more than on native ranges, the pounds of beef produced per acre on the reseeded pastures was many times greater than the production on native bunchgrass range. Moderately stocked pine-bunchgrass range produced 15.4 pounds of beef per acre. On the reseeded pastures, 75.4 pounds were produced on smooth brome, and 82.2 pounds and 85.5 pounds on the crested wheatgrass and the mixture pastures respectively. The increased production of beef is due to the greater yield of herbage on the reseeded pastures. The benefits resulting from reseeding are shown by these results. On the basis of these gains and current prices, the gross return from these pastures was from $14 to $20 in 1948. The cost of reseeding these pastures was between $5 and $6.

Reseeded pastures have high grazing capacity

Preparation of utilization tables for use in connection with the reseeded pastures has not been completed, but some observations regarding grazing use may be of interest. The three rates of stocking used on the reseeded pastures in this study are 1/4 acre, 1/2 acre, and 1 acre per cow-month, with the yearling heifers figured at 2/3 of an animal unit. The heavy rate of stocking, 1/4 acre per cow-month, had to be discontinued on all pastures about July 1, or 2 months after the grazing was started. At that time there was nothing left for the animals to graze. Some regrowth occurred after this date and the pastures were grazed for 2 weeks in early September.

The pasture stocked at the rate of 1/2-acre per cow-month provided grazing for the full 6-month period. At the end of the season, however, the grass was very short and ocular estimates of use ranged from 80 to 90 percent of the total herbage production. It is doubtful if the reseeded grasses can withstand this degree of use. On the other hand, it may be that in normal years when fall moisture is available and some regrowth occurs, the 1/2-acre per month may be adequate.

On the pastures stocked at the rate of 1 acre per cow-month, 60 to 65 percent of the herbage was left ungrazed. Grazing use was spotty; large areas of non-use were intermixed with smaller areas of heavy use. With so much herbage left at the end of the season it appears that the 1 acre per cow-month stocking rate was too light.

Forage plant adaptability trials expanded during 1948

A total of 25 different forage plants were seeded in row-plot trials at the Manitou Experimental Forest during the fall of 1948. Most of these had not been tested previously. They included twenty new grasses and weeds and five browse species, two of which had been tried previously without success. Those plantings, in addition to those made earlier, bring the total to 106 different forage plants that are being tested for adaptability to Front Range conditions.

In addition to the row-plot studies, 17 species were planted in field-plot trials at three locations on the Pike and one near the Roosevelt National Forest. The species used had all been rated as excellent for the Front Range conditions in previous row-plot trials. They were crested wheatgrass (both standard and rhizomatous), tall wheatgrass, beardless bluebunch wheatgrass, stiffhair wheatgrass, tall oatgrass, meadow brome, smooth brome, orchardgrass, Russian wild-rye, Arizona fescue, meadow fescue, red fescue, and big bluegrass. Plantings were made on depleted range at Three-Mile and on the Richaborger allotment and on abandoned farm land at the Manitou Experimental Forest on the Pike National Forest, and on the head of the Laramie River on private land near the Roosevelt National Forest.

An interesting observation regarding soil conditions was made in connection with these field-plot trials. For most seedbed preparation plowing with a Ford tractor and 2-bottom plow to a depth of 6 to 8 inches can be accomplished at 3/4 throttle in second gear. On the areas of depleted range that were plowed for these field plot tests it required full throttle in low gear to plow 2 to 4 inches deep. A power-driven posthole digger could not be made to penetrate the soil more than 2 to 4 inches. These conditions, which probably resulted from trampling and drought, explain in part the slow recovery of depleted ranges.

Methods-of-seeding study started at Manitou

During the fall of 1948 a small study of methods of seeding was started at the Manitou Experimental Forest. This study was designed to answer the two questions most frequently asked by visitors: How much should be planted, and what row spacing should be used. The study is a replicated block design including three row spacings: 8, 16, and 24 inches; and three rates of sowing: 2, 3, and 6 pounds per acre. Herbage yield will be used for evaluating the methods.

COOPERATORS

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CENTRAL PLAINS EXPERIMENTAL RANGE

The Central Plains Experimental Range is the work unit of the Rocky Mountain Forest and Range Experiment Station assigned to range research studies on Great Plains range problems. It is located in northern Weld County, Colorado, about 25 miles southeast of Cheyenne, Wyoming. The vegetation is typical shortgrass range type and it is representative of millions of acres of shortgrass ranges in eastern Wyoming and Colorado, and western Kansas and Nebraska.

Range research at the Central Plains Experimental Range is done in cooperation with the Soil Conservation Service on a portion of the Briggsdale Unit of the Northeastern Colorado Land Utilization Project. The Crow Valley Livestock Cooperative Association leases the federally owned lands of the Briggsdale Unit from the U. S. Department of Agriculture. Individual members of the Association own the cattle that are used to graze the pastures on the Experimental Range.

The 1948 research program at the Central Plains Experimental Range continued the major studies that have been in operation for several years. Field work on the intensity-of-forage-use study was completed during 1948. Another year's data were obtained on the season of forage use and protein and mineral supplement studies. Minor studies in methods of measuring forage production and in measuring forage use were in operation again this year.

1948 was a drought year

Precipitation was the third lowest of the 10 years (1939-1948) for which we have rainfall records. The rainfall for 1948 was 7.92 inches. In 1939 it was 5.20 inches and in 1943 it was 7.78 inches. The average annual precipitation for the past 10 years was 11.50 inches.

The growing-season (May - September) rainfall during 1948 averaged 5.80 inches for the 25 pasture gages. It exceeded the 2.19 inches for 1939 and the 5.57 inches received in 1944. Variations between pasture gages were quite marked in 1948 for both the amount and time of arrival of the growing-season rainfall. The low pasture received but 4.72 inches while the high pasture received 6.64 inches of precipitation. June was the high-rainfall month for 14 pastures, July was high month for one pasture and 10 pastures received the most rain during August. The variation in pasture rainfalls resulted in rather wide fluctuations from pasture to pasture in the time of maximum herbage growth and in the length of time that green forage was available to the cattle. The fluctuations in the quantity and quality of forage are reflected in the pattern of monthly average cattle weight gains made in 1948.

Forage production in 1948 was the lowest since 1939

The yield of air-dry grass from grama and buffalograss averaged 430 pounds per acre in 1948. The drought-year yield of 335 pounds in 1939 was the only lower yield during the past 10 years. The severe drought conditions which prevailed until late May and the below average growing-season rainfall were the chief factors contributing to the low forage yield in 1948.

Grazing treatments applied to the pastures for the past several years help to account for an average yield of 305 pounds of air-dry grass per acre from pastures where heavy grazing use of the vegetation has been made for the past 8 years; 449 pounds per acre from pastures where moderate grazing use was made; and 438 pounds from pastures subjected to light grazing use. Pastures on which the grazing use of the vegetation has been deferred until after August 1, each year of the past 5 years, produced 603 pounds per acre. Similar pastures on which stocking to make moderate use of the vegetation by August 10 has been practiced each year for the past 5 years produced less than 300 pounds of air-dry grass per acre.

Secondary grasses such as needle-and-thread (*Stipa comata*), bluestem wheatgrass (*Agropyron smithii*), and Indian ricegrass (*Oryzopsis hymenoides*) made very scant growth during the spring of 1948. There was an acute shortage of green feed to go with the old feed and early-season shortage of green feed resulted in low cattle weight gains for May and June.

RANGE MANAGEMENT

Grazing Studies

Cattle weight gains

Cattle weight gains during the summer of 1948 were lower than the gains for any other year since 1939. The pattern of monthly gains also was different from the patterns of monthly gains for previous years. The usually high May and June gains were not made this year. July had the highest average gain and August had the second highest average gain in 1948. The September gains were below, and the October gains were above the long-time averages for these months. Table 1 gives the 8-year (1940-1947) weighted average gains and the 1948 weighted average gains by months.

Table 1.--Weighted average cattle gains - C.P.E.R.
All pastures, by months 1940-1947, and 1948

Months	8-year average, 1940-1947	Average for 1948
	Pounds	Pounds
May	69.5	43.0
June	64.1	31.9
July	56.4	61.1
August	48.4	55.6
September	33.1	26.5
October	0.7	11.6
Season totals	272.2	229.7

The relatively low gains in May and June 1948 were the chief factors influencing the low average seasonal gains for 1948.

Cattle weight gains varied widely in 1948

Average weight gains made by the cattle under different stocking rates of the intensity-of-use study showed wide variations again in 1948. In this experiment, 4 of the 12 pastures are stocked with a sufficient number of yearling cattle to make heavy grazing use of the vegetation by the end of the summer grazing season. Four other pastures are grazed by fewer cattle to obtain moderate use of the vegetation. The remaining four pastures are stocked with a small number of cattle in each pasture so that light use of the vegetation is made each year. The four heavily stocked pastures have been heavily stocked each of the past 9 years. Similarly, each of the moderately and lightly stocked pastures has had the same grazing treatment applied to it for 9 years. The cumulative effects of continued grazing treatments are being studied.

Adverse weather conditions retarded the growth of the vegetation in all 12 pastures during May and early June of 1948. The volume of feed available to the cattle in the pastures stocked for heavy grazing use was limited during the early months. Plenty of old feed left from the 1947 crop was available to the cattle in the pastures stocked for moderate and light use of the vegetation. New green feed to balance the old feed, however, was very limited and the weight gains made on these pastures were not up to the long-time averages for May and June. The average monthly weight gains by grazing treatments for 1947 and 1948 are shown in Table 2.

Table 2.--Average cattle weight gains made on the intensity-of-use pastures - C.P.E.R. - 1947 and 1948

Items	Degree of forage use					
	Heavy		Moderate		Light	
	1947	1948	1947	1948	1947	1948
Number of yearling cattle per section	75	70	42	42	23	24
Average gain per head			Pounds			
May	75	39	82	46	75	47
June	60	24	58	34	63	39
July	48	56	51	65	46	64
August	51	47	48	59	52	60
September	19	12	35	22	34	18
October	-22	-8	-4	12	12	27
Total for 6 months	231	170	270	238	282	255

The moderately stocked pastures produced an average gain of 238 pounds per head in 1948. This is 68 pounds greater than the 170 pounds per head produced on the heavily stocked pastures. The weight gains made on the lightly stocked pastures averaged 255 pounds per head. This is 85 pounds greater than the 170 pounds produced on the heavily stocked pastures, but only 17 pounds greater than the 238 pounds produced on the moderately stocked pastures.

Moderate grazing use gave high returns per section in 1948

The gross returns obtained from harvesting and marketing the forage crop from a section of range land through cattle at the three stocking rates are highly in favor of the moderate and light stocking rates. When 42 yearling cattle per section were used they consumed 42.5 percent of the current growth of the vegetation and produced a gross return to the range operator of $1256.41 for the forage crop. Seventy yearling cattle per section in the heavily grazed pastures used 60 percent of the current growth of vegetation, but they returned only $209.01 gross for the forage crop. Twenty-four yearlings per section consumed about 20 percent of the vegetation and returned the range operator $869.24 gross for the forage crop from the section of range land. Table 3 gives the 1948 data on a per-section basis for the 12 pastures -- 4 in each treatment -- under this type of management at the Central Plains Experimental Range.

The returns from moderate use were $1047.40 greater and the returns from light use were $660.23 greater per section than those obtained under heavy grazing use of the vegetation. These differences per section on a 10-section ranch could very easily determine whether the operator remained in the business or not.

Cattle gains on early-season pastures were much lower in 1948

The cattle weight gains produced on half-section pastures that are heavily stocked during the first 3 months of the summer grazing season were lower in 1948 than any of the other 5 years this study was operated. The average gain per pasture for the late-season pastures was the highest of the 6 years. In this experiment three pastures -- one each in the saltbush-grama, grama-meadow, and grama-buffalograss vegetation subtypes -- are grazed for the first 3 months of the summer season by twice the number of cattle that would make moderate use of the vegetation in 6 months. Three other pastures are grazed during the last 3 months of the summer season by the cattle used in the early-season pastures. Three check pastures, one in each subtype, are stocked for moderate utilization of the vegetation in 6 months. The same half-section pastures have been used for early, late, and season-long grazing for the past 6 summers. Sixty head of yearling cattle are used in the seasonal pastures and thirty head in the check pastures in the saltbush-grama and grama-meadow pastures. Forty and twenty head are used in the grama-buffalograss pastures. Table 4 gives the total gains made per half-section pasture in 1943, and each of the past 3 years. The 1944 and 1945 data, omitted to save space, are generally intermediate between the 1943 and 1946 figures for the early- and late-season pastures. The weight gains in the season-long pastures have not shown any upward or downward trend.

Table 3.--Gross returns per section of range forage
Intensity-of-forage-use study - C.P.E.R. 1948
Based on 12 pastures

Items	Degree of forage use		
	Heavy	Moderate	Light
Average number head per section	70	42	24
Average initial weight May 11 - pounds	426	427	446
Average final weight Nov. 5 - pounds	596	665	701
Average gain per head - pounds	170	238	255
Average initial value per cwt. 1/	$ 24.50	$ 24.50	$ 24.50
Average initial value per head	104.37	104.62	109.27
Average final value per cwt. 2/	19.00	21.00	21.50
Average final value per head	113.24	139.65	150.72
Gross sales value of cattle per section of rangeland	7,926.80	5,865.30	3,617.28
Cattle costs per section			
Value of stocker cattle in May	7,305.90	4,394.04	2,622.48
Interest on cattle at 5% - 6 mos.	182.65	109.85	65.56
Misc. costs - salt, vaccination, spraying, taxes, transportation, etc. at $2.50 per head	175.00	105.00	60.00
Actual death loss	54.24	0.00	0.00
Total cattle costs per section	7,717.79	4,608.89	2,748.04
Gross returns from forage crop per section of rangeland 3/	209.01	1,256.41	869.24
Difference in favor of moderate and light use over heavy use		1,047.40	660.23

1/ Based on average bulk of sales price at Denver for good grade stocker heifers during the week including May 7, 1948.

2/ Market appraisal of cattle (Denver basis) made by commercial cattle feeders from the Greeley, Colorado, area.

3/ These are gross returns for the sale of the forage crop through cattle. Range costs such as taxes on land, fence and water facilities maintenance and depreciation, labor to handle the cattle, etc., have to be deducted before net returns are obtained.

Table 4.--Comparison of total weight gains made by cattle per half-section pasture as affected by season-of-forage use Shortgrass range - C.P.E.R. 1943-1948

Pasture sub-type and season of use	Total gain per half-section pasture			
	1943	1946	1947	1948
	Pounds			
Saltbush-grama				
Early-season (60 head 3 mos.)	12,984	9,906	12,000	7,560
Late-season (60 head 3 mos.)	6,690	4,704	5,160	7,404
Season-long (30 head 6 mos.)	9,153	8,328	8,280	8,073
Combined use (60 head 3 mos. on each pasture) 1/	9,837	7,305	8,580	7,482
Difference	684	-1,023	300	-591
Grama-meadow				
Early-season (60 head 3 mos.)	11,388	9,642	10,680	7,638
Late-season (60 head 3 mos.)	6,388	4,080	4,140	5,178
Season-long (30 head 6 mos.)	8,649	8,298	8,820	7,749
Combined use (60 head 3 mos. on each pasture) 1/	8,888	6,861	7,410	6,408
Difference	239	-1,437	-1,410	-1,341
Grama-buffalograss				
Early-season (40 head 3 mos.)	7,964	5,288	6,640	4,028
Late-season (40 head 3 mos.)	3,896	4,056	3,160	5,444
Season-long (20 head 6 mos.)	5,348	4,780	5,180	4,154
Combined use (40 head 3 mos. on each pasture) 1/	5,930	4,672	4,900	4,718
Difference	582	-108	-280	564

1/ Figures obtained by dividing the gains made on two half-section pastures (early plus late) by 2.

The sharp reduction in gains for 1948 from the early-season pastures was due in part to the low volume of feed available to the cattle and the rather acute shortage of green feed during May and early June. The cattle did not make the growth during the early season in 1948 that they made during that period in other years. This lack of development at the time of their transfer to the late-season pastures could have been a factor in the high weight gains made by the cattle on the ample forage available to them in the late-season pastures this year. In 1948 the cattle had a greater potential for gain at the time of the midseason change in pastures than the cattle had at that time in previous years.

Except for 1947, an outstanding forage-production year, the weight gains produced on the early-season pastures have declined from year to year. These gains on all three vegetation subtypes in 1948 were less than the gains produced on similar adjoining pastures grazed season-long by half as many cattle. This reduction in meat-producing capacity and the declining range condition of the pastures that have been heavily stocked from May to August indicate that heavy early-season use of shortgrass range vegetation is a very undesirable range management practice.

Protein and mineral supplements did not pay in 1948

Steers that were fed protein and mineral supplements in addition to summer range made smaller weight gains than were made by steers on summer range without supplement. In this study three similar half-section pastures were stocked with 15 steers each for light to moderate use of the vegetation. Protein supplement in the form of cottonseed cake was fed in one pasture from August 15 to November 5. A commercial range mineral with a narrow calcium-phosphorus ratio was fed all summer in a second pasture. The steers in the third pasture were the check cattle, and had range feed only. Two smaller pastures were stocked for moderate use of the vegetation. Cottonseed cake was fed in one of them from July 15 to November 5. Block salt was available to the cattle in all pastures all summer. The steers were sorted carefully in May for uniformity between pasture groups. Appraisal of the market values of the pasture groups was made by a commercial cattle feeder in November. Table 5 gives the average gain per head and the appraisal price per hundredweight in early November.

Table 5.--Average gain per head and market appraisal of steers in protein and mineral supplement pastures

Treatment in addition to range forage and salt	Gain per head 6 months	Market appraisal per cwt. 1/
	Pounds	
Lightly grazed pastures		
Cottonseed cake	312	$25.50
Mineral supplement	308	25.00
Check (none)	316	26.00
Moderately grazed pastures		
Cottonseed cake	249	23.00
Check (none)	258	24.00

1/ The cooperation of Mr. A. W. Avery in making the fall appraisal of the cattle is greatly appreciated.

Under both light and moderate degrees of forage use the check cattle made more pounds of gain and they were valued at a higher price per hundredweight than the cottonseed cake-fed cattle. The steers that were fed a mineral supplement made less weight gain than either the cake-fed or check cattle. The check steers were appraised at one dollar per hundredweight more than the mineral-fed steers.

The steers receiving cottonseed cake on grass in the pasture stocked for moderate utilization of the vegetation spent considerable time late in the season waiting for their cake feed. They did not get out and rustle for range feed as did the steers that were not receiving cake. The cake-fed steers lost 10 pounds per head in weight during October, while the steers

that did not get cake in addition to range feed made a 7-pound-per-head gain in weight. These check cattle also were appraised one dollar higher per hundredweight than the cake-fed cattle.

Although the 1948 summer season was quite dry and the range forage cured early -- conditions generally expected to favor the use of protein supplements -- no advantage was obtained from feeding cottonseed cake in addition to summer range feed. In fact, the cost of both the cake and the mineral and the expense of the labor and transportation to feed them was lost. In comparison to 1947 when range feed was abundant and remained green relatively late in the season, the 1948 results are quite striking. Protein supplement in 1947 paid for itself on the moderately stocked range and returned some profit from its use in the lightly stocked pasture.

Heavy grazing resulted in lower market appraisals

Representative lots of heifers from the intensity-of-use pastures were appraised in 1948 as follows:

	Value per cwt.
Heavy utilization	$19.00
Moderate utilization	21.00
Light utilization	21.50

The relatively wide spread in the fall appraisal values between the thin heifers from the heavily stocked pastures and the fatter heifers from the moderately and lightly stocked pastures is worth noting. This price spread applies to the initial weight of the stocker cattle just the same as it applies to the gain in weight produced during the grazing period.

Vegetation Studies

Density of vegetation was lower in 1948

The percentage of the ground covered by green vegetation in July 1948 was only 9 percent. In July 1947 it was 12.7 percent. A difference in the percentage of the ground cover is to be expected between a good year for vegetation growth like 1947 and a year like 1948 when climatic conditions were unfavorable to the growth of range vegetation. The average ground cover in 1948 was only 70.7 percent of the average ground cover for 1947.

Changes in density from 1947 to 1948 were influenced by past grazing treatments of the pastures

Changes in vegetation density from 1947 to 1948 were not uniform from pasture to pasture. The ground cover produced by vegetation classes such as grasses, weeds, and browse plants, also did not make uniform changes from one year to the next. Table 6 gives the percentage of the 1947 density present in 1948 by vegetation classes in the intensity-of-use pastures.

Table 6.--Percentage of 1947 vegetation density present in 1948. Intensity-of-forage-use pastures

Vegetation classes	Degree of forage use		
	Heavy	Moderate	Light
		Percent	
All vegetation	68.2	77.7	74.8
All grasses	70.5	81.3	82.2
All weeds	35.9	32.6	22.1
Browse	58.4	69.6	57.8
Blue grama	66.5	76.5	81.1
Buffalograss	119.9	112.2	106.0

Pastures that have been stocked for moderate and light use of the vegetation for the past 9 years lost less in total density from 1947 to 1948 than did the pastures that were stocked for heavy use of the vegetation. Grass plants, which are high in forage value as compared to weeds and browse plants, produced over 80 percent of their 1947 ground cover on the moderate- and light-use pastures as compared to only 70 percent of their 1947 ground cover in the heavy-use pastures. Weeds, however, had less loss of density from 1947 to 1948 in the heavy-use pastures. The loss in browse density was least in the moderate-use pastures while it was greatest in the light-use pastures.

The different reactions of blue grama (Bouteloua gracilis) and buffalograss (Buchloe dactyloides) is of interest. Buffalograss actually produced more ground cover in 1948 than it did in 1947, under all three degrees of grazing use. The increase was the largest in the heavily stocked pastures. Blue grama lost the most ground cover in the heavily stocked pastures and the least in the lightly stocked pastures. The taller grass species like bluestem wheatgrass (Agropyron smithii) and needle-and-thread (Stipa comata) were greatly reduced in ground cover from 1947 to 1948. Their loss was all but total in the heavy-use pastures, about 75 percent in the moderate-use pastures, and 50 percent in the light-use pastures.

Table 7 gives the percentage of the 1947 vegetation density present in 1948 on the season-of-use pastures. The pastures that have been grazed during the first 3 months of the summer season suffered the greatest loss of ground cover from 1947 to 1948, while the pastures used late in the season had the smallest loss. The pastures grazed season-long by half as many cattle suffered losses about intermediate between the losses occurring on the other two groups of pastures. Ground cover by buffalograss made sharp increases in the early-season pastures where the losses in blue grama density were the largest. Buffalograss also made some increase in density in the pastures used season-long, but in the late-season pastures it suffered slightly larger losses than did blue grama.

Table 7.--Percentage of 1947 vegetation density present in 1948. Season-of-use pastures

Vegetation classes	Season of use		
	Early	Late	Summer-long
		Percent	
All vegetation	64.3	72.4	67.9
All grasses	62.0	76.0	70.1
All weeds	63.7	56.7	35.2
Browse	99.2	59.1	57.8
Blue grama	57.9	74.4	66.6
Buffalograss	317.0	73.4	108.9

Blue grama decreased 25 percent in weight between October and April

Twenty-five percent of the weight of air-dry blue grama on the range in October disappeared by early April from causes other than livestock grazing. Four hundred small plots were established in a uniform stand of blue grama range in the spring of 1947. The plots were varied in size so that each plot carried 1 square foot of ten-tenths density of blue grama. All plots were protected from grazing by domestic livestock. Antelope and rabbits were not excluded. Clipping treatments were applied to a number of these plots during the summer of 1947. The vegetation on 120 of them was allowed to grow all of the growing season. The blue grama herbage was clipped from 40 of the 120 plots about the middle of October 1947. This vegetation was air-dried and weighed as a measure of total growth that year. The grama vegetation was clipped from a second 40 of the 120 plots on February 23, 1948. This vegetation was air-dried and weighed. The remaining 40 plots were clipped on April 9, 1948, and the vegetation was air-dried and weighed. Mean weights of the grass clipped on February 23 and April 9, 1948, measured the amount of the 1947 growth remaining on the range to those dates. Losses in weight from October to February, October to April, and February to April measured the disappearance of blue grama herbage due to influences other than livestock grazing. The essential data from this experiment are in Table 8.

Table 8.--Loss in weight of cured blue grama on the range from October to February and to April

Treatment	Average weight of air-dry grass per plot	Deviation from check	
	Grams	Grams	Percent
Protected all of growing season and clipped in October 1947 - Check	36.28	0.00	0.00
Protected all season and clipped Feb. 23, 1948	29.58	-6.70	-18.40
Protected all season and clipped April 9, 1948	27.18	-9.10	-25.08

Blue grama herbage remaining on the range but protected from livestock grazing lost over 18 percent of its air-dry weight from October to late February. Early in April the loss in weight amounted to a little over 25 percent of the October weight. The loss of 6.70 grams per plot from October 15 to February 23, and the loss of 2.40 grams per plot from February 23 to April 9, are almost proportional to the lengths of time over which the losses occurred. This loss in weight is not a loss in the sense of being wasted. Even though the herbage was not consumed by livestock it did serve a very important purpose in that it returned nutrients and humus to the soil.

COOPERATORS

We wish to acknowledge the assistance of the following cooperators:

Crow Valley Livestock Cooperative Association, Briggsdale, Colorado

Soil Conservation Service
Willard Graves, Range Technician, Fort Collins, Colorado
Neal P. McKinstry, Project Manager, Briggsdale, Colorado

A. W. Avery, Eaton, Colorado
Elmer P. Ball, Briggsdale, Colorado
Duncan Calder, Nunn, Colorado
A. T. DePorter, Carr, Colorado
Murray Giffen, Nunn, Colorado
Kermit Golgart, Purcell, Colorado
G. H. Groves, Eaton, Colorado
Floyd J. Mason & Son, Grover, Colorado
James McCartney, Briggsdale, Colorado
McKay Brothers, Grover, Colorado
Warren Monfort, Greeley, Colorado
F. E. Murphy, Briggsdale, Colorado
H. B. Pollock, Nunn, Colorado
Russell Pollock, Nunn, Colorado
Henry Prange, Carr, Colorado
Harry Raven, Purcell, Colorado
George Verbich, Purcell, Colorado
Fred Werner, Briggsdale, Colorado
Frank R. Williams, Nunn, Colorado

WYOMING RESEEDING STUDIES

A rough estimate by the Range Management Department of the University of Wyoming shows 1,500,000 acres of range land in Wyoming in need of reseeding. The reseeding problem analysis of the Rocky Mountain Forest and Range Experiment Station indicates that most of this land is in the sagebrush and saltsage-desert types. Little of this land has been seeded. Furthermore, attempts at seeding have been accompanied by numerous and often costly failures.

It has been recognized for a number of years that research was needed to provide information for species and methods of seeding Wyoming ranges, but funds have not been and are not yet available for this purpose. However, because of an urgent request by the Bureau of Land Management for help with their administrative seeding program, a small beginning was made in reseeding research in Wyoming in 1948.

Research studies started on a cooperative basis

The Bureau of Land Management and the Rocky Mountain Forest and Range Experiment Station joined in deciding upon the program, selection of seeding sites, methods to be used, species to be planted, and doing the seeding. The former agreed to furnish the land, prepare the seedbed, and provide protection from livestock. The latter agreed to furnish the seed, take all records, and make all reports. To avoid duplication of past and present work, the types of investigation and the locations for doing the work were discussed with staff members of the Wyoming Agricultural Experiment Station.

Since all phases of the reseeding problem could not be studied at once, it was decided that first efforts would be to determine adapted species for future seedings and to see the effect of seedbed preparation upon establishment and growth of these species.

Twenty-one forage plants tested on 211 plots at 11 locations in the sagebrush and saltsage types

Cooperative work was commenced in April of 1948 when one burned sagebrush area north of Lost Cabin was drilled to nine grasses and one clover; and two depleted saltsage areas, one at Arminto and one west of Worland, were drilled to seven grasses each. Despite the dry summer, the seedlings made a good start and by the end of the summer there were good stands of crested wheatgrass and Russian wild-rye, fair stands of intermediate and tall wheatgrass, and poor stands of Indian ricegrass and stiffhair and western wheatgrass on the two saltsage areas. Native grass which was present on the sagebrush burn at Lost Cabin grew vigorously and prevented establishment of good stands of reseeded seedlings.

In the fall of 1948 experimental plots were seeded on eight additional areas as follows: In the sagebrush near Lander, Sweetwater, and Worland; and in the saltsage near Kane, Manderson, south of Riverton, south of Moneta, and south of Casper. The number of species varied with the area and varied from 7 of the most drought-resistant grasses seeded on dry sites to 21 grasses and clovers seeded on good sagebrush lands. Sagebrush on the areas near Worland and Lander was killed before seeding. On the other five areas, one-half of

the total plot area was cleared of sagebrush or saltsage by grading. Seeding was done with a drill on both the cleared and uncleared portions of the plot area. By drilling at right angles to the cleared strips, one-half of each individual grass plot was cleared before drilling and half was not disturbed. Thus, in addition to determining species for seeding sagebrush and saltsage lands, this will be a test of the value of removing brush prior to drilling.

Altogether, 211 plots were seeded; 48 in the spring and 163 in the fall. These plots will be a test of the 20 grasses and the 1 clover, and will show the value of clearing brush on the 11 seeded areas.

COOPERATORS

We wish to acknowledge the assistance of the following cooperators:

Bureau of Land Management
John Killough, Range Conservationist, Lander, Wyoming
Floyd Larsen, Range Conservationist, Billings, Montana
W. T. Vaughn, Range Conservationist, Lander, Wyoming

A. A. Beetle, Agricultural Experiment Station, University of Wyoming, Laramie, Wyoming

A soil and physical survey was completed of the Manitou Experimental Forest

The survey of the soil and physical conditions of the Manitou Experimental Forest in progress at intervals during 3 years was completed in 1948. An illustrated report with accompanying maps is being prepared.

The project revealed a wide variety of different soils and different degrees of soil development. Most of the soil parent materials are biotite granite (Pikes Peak granite) or alluvium from these rocks. Other important soil parent materials are Fountain sandstone, Madison limestone, and Sawatch quartzite. The limestones produce by far the most productive soils, while the quartzites and granites are poor in this respect.

Information gained from this survey is applicable to a wide area of the Front Range of Colorado. The knowledge of erosion conditions and stream development can be widely used in Watershed Management in areas where conditions are similar to those on the Experimental Forest.

Preliminary studies were made of soils in alpine areas

Preliminary studies were made of soils developed above timber line near the Continental Divide at intervals from southern to northern Colorado. The soils contain well developed surface soils 10 to 15 or more inches thick. The top 5 inches is very firmly held together by the thick root mass of the alpine turf. Much fine soil material occurs in the rocks as deep as 40 inches in some places. The soils are well drained, intermediately drained as in willow fields, and poorly drained as in peat bogs. Different rock types tend to produce different soils but these differences have not been great in the areas studied.

The alpine areas are important watershed lands. Snowbanks melting all summer feed water down through talus slopes to replenish streams and glacial lakes. On more gentle slopes seeps originate 200 to 400 feet below the crests of peaks and sometimes within 50 feet of the crests. The seeps feed large willow fields and contribute much water to some of the larger streams that feed the rivers below. Frozen subsoils were found in a few of these seep areas late in the summer. The water may result in part from the melting of ice in these deep soil layers. Likewise, these frozen soils may be in part responsible for seeps originating high on the mountain sides, the frozen soil acting in much the same way as a hard pan or bedrocks in preventing deep percolation of water.

Heavy grazing has caused deterioration of the turf and accelerated erosion in some areas studied. The areas most severely affected are on soils developed from shales and coarse-textured granites. Studies in Rocky Mountain National Park and elsewhere indicate that recovery of raw areas by the alpine turf is a very slow process.

Fertilizer plots on range lands show no conclusive results during second season

The seven fertilizer plots established on different grassland soils in 1947 showed no definite response in 1948. Fourteen different fertilizers were used. They were applied as a top dressing to native range plants. In 1947 nitrogen gave a response on most soils. However, in 1948 all beneficial effects from the nitrogen application had disappeared. Vegetative response to the other fertilizers was not apparent. In addition to nitrogen, potassium, and phosphorus, the minor elements used were calcium, boron, cobalt, copper, iron, magnesium, manganese, molybdenum, sodium, sulfur, and zinc.

(Bureau of Entomology & Plant Quarantine in cooperation with Forest Service)

The very serious outbreaks of the Engelmann spruce beetle, mountain pine beetle, and Black Hills beetle in the central Rocky Mountain forests placed a heavy assignment on the forest entomologists of providing technical assistance on the problems and development of better control measures. As a result, some of the planned research had to be curtailed to meet the emergency. Fortunately, the results from some of the research on improvement of methods for control of the Black Hills beetle were sufficiently advanced to put into practice the spraying of standing trees with a mixture of one part orthodichlorobenzene to six parts fuel oil. This new and more economical method of treating infested trees contributed in no small way to the accomplishments on the bark beetle control projects in 1948. Other lines of research continued during the year were biological control of the spruce budworm and control of pine tip moths with DDT.

Black Hills beetle control successful

The treatment of 54,454 ponderosa pine trees infested with the Black Hills beetle in the Black Hills of South Dakota and Wyoming has averted serious losses. It was an outbreak that could have become as serious as the one 40 years ago, which killed more than 1 billion board feet of pine before subsiding. The state of South Dakota and the Homestake Mining Company treated 1,506 and 2,003 trees respectively under cooperative agreement involving financial assistance under the Forest Pest Control Act. The remainder, or 50,945 trees, were treated by the Forest Service. That the treatment was effective is indicated in the greatly reduced number of trees attacked in 1948. The survey estimates show approximately 16,000 trees infested from the August flight of beetles. That number of trees treated during the fall of 1948 and spring of 1949 should reduce the infestation to where a small amount of annual maintenance work will keep the beetle from again reaching outbreak proportions.

Black Hills beetle reaches epidemic proportions on Roosevelt National Forest

Approximately 23,000 ponderosa pine trees on the Roosevelt National Forest were attacked and killed by the Black Hills beetle in 1948. The estimate was obtained by a survey of approximately 90,000 acres previously reported to be infested. Nearly all of the infested trees are on the northern half of the Forest. A light infestation also exists on private and city lands in the Denver Mountain Parks area and the adjacent Pike and Arapaho National Forests.

Mountain pine beetle out of control on Ashley and Wasatch National Forests

Typical of an aggressive bark beetle outbreak, the mountain pine beetle infestation in lodgepole pine on the Ashley and Wasatch National Forests in northeast Utah increased from 37,500 trees in 1947 to 112,400 trees in 1948. Although the outbreak is confined to approximately 108,000 acres,

it is liable to spread to more than one-half million acres and to kill most of the merchantable-size trees. An attempt to control the outbreak has been declared economically unsound.

Engelmann spruce beetle continues threat to Colorado spruce

The Engelmann spruce beetle outbreak, largely centered on the White River National Forest north of the Colorado River, advanced northward on the Gore Range in the Routt National Forest as far as Rabbit Ears Pass and eastward into the western edge of the Arapaho National Forest. Extensive Engelmann spruce stands on those two forests as well as those on the White River National Forest south of the Colorado River are jeopardized by this movement of the outbreak. The amount of Engelmann spruce killed in 1948 in terms of volume was much lower than during the preceding 5 years because the greater portion of the kill was in the smaller diameter classes. There remains, however, a very great beetle population in the eastern part of the White River and southern part of the Routt National Forests. The estimate of volume killed from the Colorado outbreaks, 1942 to 1948, remains at 4 billion board feet. Other outbreaks in Colorado have continued to decline since 1945. The cause of the declines is believed to be from heavy woodpecker feeding.

Black Hills beetle control costs reduced by new method

Prior to 1948 the accepted methods for control of the Black Hills beetle were to fall the infested trees and burn the stems, or to fall the trees and spray the bark with a mixture of 1 part orthodichlorobenzene to 6 parts fuel oil. It was found that the mixture was equally effective when applied to standing trees with proper spray equipment. Conventional hand spray equipment modified to meet the needs of portability and equipped with a No. 6 polished-bore solid-stream nozzle is quite efficient for treating trees that cannot be reached by motorized equipment. In areas accessible to motorized equipment, the most efficient equipment is a power sprayer with a 50-gallon tank and 400 feet of hose on a live reel mounted on the back of a jeep. A limitation of the spraying-standing method is the height of the spray -- 35 feet with hand equipment and approximately 45 feet with power sprayers. However, the spray height is sufficient to reach the upper limits of the infested stems on nearly all trees in the central and southern Rocky Mountain forests. The method was used on the control project in the Black Hills with a substantial saving in the treatment costs.

Spruce budworm outbreaks decline in South Dakota and Colorado

The outbreak of the ponderosa pine form of the spruce budworm in the Black Hills of South Dakota practically disappeared in 1948 from unknown causes. The Colorado infestations of the fir form have receded to an area of about one township on the Pike National Forest. The attempt to rear some colonies of parasites collected from the extensive outbreak on the Carson and Santa Fe National Forests for shipment to the northeast was not fruitful. Possibly the reason for the continuation of high population on those two Forests is the low degree of parasitism.

FOREST-RANGE-WILDLIFE RESEARCH

(Fish and Wildlife Service in Cooperation with Forest Service)

The field studies of pocket gopher - range relationships on the Grand Mesa National Forest, begun in 1941 in cooperation with the U. S. Fish and Wildlife Service, were continued during 1948.

Two types of study plots, fenced and unfenced, were set up on the Grand Mesa to measure the individual and combined effects of gophers and cattle on the range. These variations are again divided by treatment, half with gophers removed and half the plots leaving the gophers undisturbed. The efforts of the Fish and Wildlife Service were almost entirely occupied with preventing mass migration of gophers onto the gopher-free plots and removing those gophers which have successfully invaded these plots. The areas surrounding the study plots support a dense gopher population and there is continual invasion from this source. From October until June, Grand Mesa is snow covered, and during this period the gophers have unrestricted access to the plots in their travels through and under the snow.

To combat this migration, the gopher-free plots and a surrounding buffer strip are intensively poisoned and trapped. The lethal bait used in this poisoning is rolled oats treated with 1080 at the proportion of 2 ounces of 1080 to 100 pounds of oats. Late in the season when bait tests show that acceptance of oats drops materially, sweetpotatoes are used in place of oats to keep gopher acceptance of baits around 90 percent. Trapping is done mainly on the plots themselves to insure that those gophers which cross the buffer area without encountering the poison will be removed before they can materially damage the vegetation on which forage production and vigor will be measured.

On August 19, 1948, an inspection tour of critical range areas on Grand Mesa was made in company with Forest Service officials, permittees, and city officials of Grand Junction interested in this watershed area. While observing the pocket gopher study, it was noted that pocket gopher mounds were conspicuously absent on small experimental plots treated in 1947 with weed-killing compound (2,4-D) by the staff of the Western Slope Research Center. Since the line of demarcation was so definite on these plots, pocket gopher mounds being everywhere but on the areas sprayed with 2,4-D, there was much comment as to whether the complete weed removal--and therefore the removal of the main gopher food supply--was responsible for the absence of gophers on these areas. If money and manpower permit it would be highly desirable to treat a large area in this manner and check the gopher population before and after spraying with 2,4-D to see whether the weed removal would materially affect the number of gophers present.

During December a trip was made to Grand Mesa to add to the knowledge of year-round gopher activity. At that time, only a single example of gopher activity above the ground was encountered in 300 feet of trench dug through the snow in an area known to be heavily infested with gophers. Winter observations will be made again to determine the time at which masses of earth are moved into the snow by the gophers.

APPENDIX

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STATION PERSONNEL
(As of December 31, 1948)

Administration	
W. G. McGinnies	Director
Clarence L. Newman	Administrative Asst.
Marie D. Garwood	Clerk-Stenographer
Betty B. Tinsman	Clerk-Typist
Mona F. White	Clerk-Stenographer
Special Soils Investigations	
John L. Retzer	Soil Scientist
Forest Management	
Bert R. Lexen, Division Chief	Silviculturist
Forest Influences	
L. Dudley Love, Division Chief (Appt. 6/23/48)	Forester
Range Management	
David F. Costello, Division Chief	Range Conserv.(Res.)
Alvin C. Hull, Jr. (Trans. 2/2/48 from INT)	Range Conserv.(Res.)
Central Plains Experimental Range	
Graydon E. Klipple	Range Conserv.(Res.)
Frank R. Williams	Unsk. Laborer

Front Range Research Center

(Manitou Experimental Forest, Woodland Park, Colorado)

Wallace M. Johnson, Acting RCL	Range Conserv. (Res.) Range
Earl G. Dunford	Soil Scientist (Influences)
Ned A. Smith (Appt. 2/1/49)	Range Conserv. (Res.) Range
Thorkild W. Hansen	Agricultural Aid

Continental Divide Research Center

(Fraser Experimental Forest, Fraser, Colorado)

Bert R. Lexen, Acting RCL	Silviculturist (Forest Mgt.)
Ezra M. Hornibrook	Silviculturist (Forest Mgt.)
Bertram C. Goodell	Conservationist (Influences)

Western Slope Research Center, Delta, Colorado (temporary)

George T. Turner, Acting RCL	Range Conserv. (Res.) Range
Clyde W. Doran	Range Conserv. (Res.) Range
Edward L. Dortignac	Conservationist (Influences)

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W. D. Buchanan	Entomologist
Calvin Massey	Entomologist
W. F. McCambridge	Forestry Aid
Sue Heard	Clerk-Stenographer

Fish and Wildlife Service

M. W. Cummings	Biologist